THE LONE STAR CEMENT PLANT, AND THE SOUTHEAST MISSOURI PORT, CAPE GIRARDEAU COUNTY, MISSOURI

ASSOCIATION OF MISSOURI GEOLOGISTS

35th Annual Meeting and Field Trips

September 23 and 24, 1988

Cape Girardeau, Missouri

Sponsored by the

DEPARTMENT OF EARTH SCIENCES,

SOUTHEAST MISSOURI STATE UNIVERSITY

with the cooperation of

LONE STAR INDUSTRIES, INC.

and

SOUTHEAST MISSOURI REGIONAL PORT AUTHORITY

ASSOCIATION OF MISSOURI GEOLOGISTS
35TH Annual Meeting and Field Trip
September 23 and 24, 1988
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Acknowledgements

Many persons have my heartfelt gratitude for their contribution to the planning and development of the field trips, meeting, and the guidebook.

Particular thanks go to the members of the Planning Committee. Ray Knox made extensive contributions to the guidebook. Andy Childers was instrumental in arranging the Lone Star plant trip. Mike Klosterman provided the technical material for the guidebook on the Port trip. Lou Unfer made sure of ample refreshments.

At Lone Star, John Vontress, Technical Manager, and Fred Aukeman, Quarry Supervisor, along with Andy Childers, provided the technical materials for the guidebook. They set up the tour of the quarry and plant.

Planning for the Port tour was helped by Tom Cooley and Alan Maki, past and present Directors of the Port Authority. Peter Kinder, Port Commissioner, provided the history of the development of the Port for the guidebook. Jim Lawson of Bowen & Lawson provided technical advice on the Port.

Dave Stewart, Executive Director of the Central United States Earthquake Consortium, agreed to his timely presentation on CUSEC for the Meeting Program, even though his daunting schedule was packed around the date.

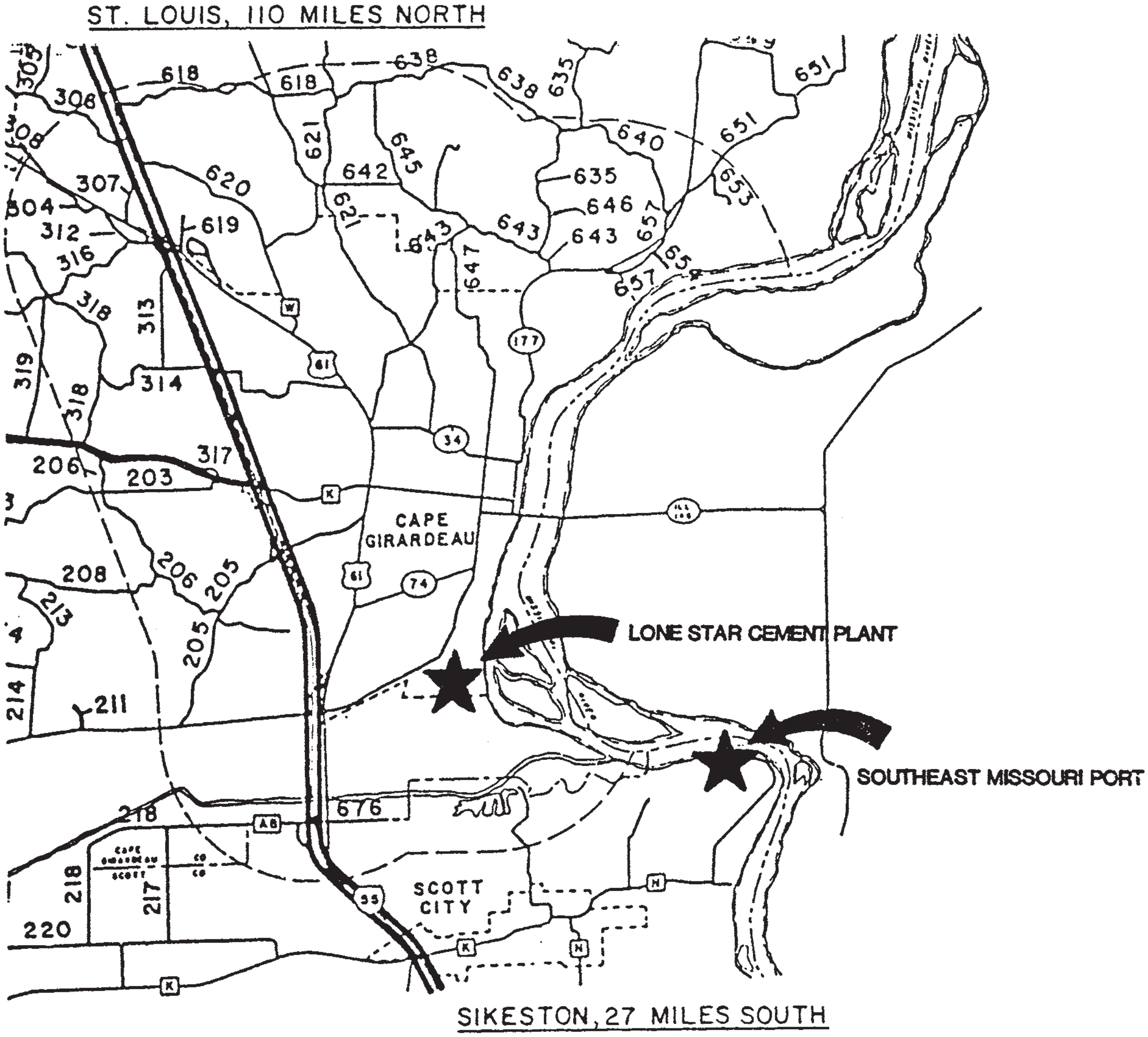
Jerry Vineyard, AMG Past President, did his best to arrange spectacular transportation for the Saturday trip. He obtained permission to use the Corp of Engineers barge. Unfortunately, we just could not come up with a tug to move the barge. Do enjoy the bus ride!

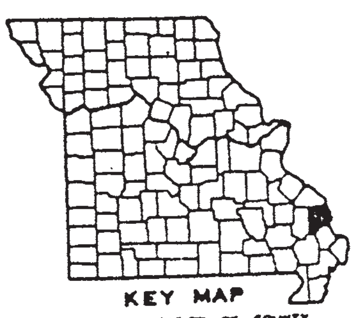
Mimi Garstang, AMG Secretary-Treasurer, made sure, by gentle reminder, that everything got done on time, and provided excellent advice whenever I needed help.

Again, my thanks to all these individuals. For everything that goes right on this trip, they deserve the credit.

Nick Tibbs
AMG President Elect

LOCATION MAP OF FIELD TRIP SITES





Geology of the Cape Girardeau Urban Area

Editor's note: The following information was excerpted with permission of the author from Physical Geology of the Cape Girardeau - Jackson Urban Area, Cape Girardeau County, Missouri by Kent M. Bratton. Southeast Missouri Regional Planning Commission Geological Planning Report No. 1, 1974 (out of print.) Kent is now Cape Girardeau's City Planner.

Physiographic Divisions

The Cape Girardeau-Jackson area encompasses parts of five distinct physiographic divisions, each characterized by a general type of topography and a common geological origin. These divisions are outlined to facilitate the discussion of planning considerations for areas with like physical features. The five divisions present in the area are indicated in Exhibit No. 12.

The county as a whole lies within two separate physiographic provinces. The southern portion, extending southward from the bluff line along Missouri 74 lies within the Southeastern Lowlands section of the Mississippi Embayment Province. The area north of the bluff line lies within the Salem Plateau section of the Ozark Plateaus Province. The Salem Plateau extends eastward through Perry and Cape Girardeau Counties into the Shawneetown Ridge, or Shawnee Hills, of southern Illinois. The Mississippi Embayment extends southward to the mouth of the Mississippi River. The physiographic divisions outlined in this report are smaller divisions of the provinces and sections just mentioned.

The most striking physiographic division in the county is the Cape Hills area to the northeast of Cape Girardeau. This area is commonly referred to as the "River Hills" locally and was previously referred to as the Bailey Platform by R. F. Flint (Gealy, 1955, p. 7). Flint's naming of the platform and the escarpment (Bailey) that forms its western boundary was based on the presence of cherty limestones of the Bailey Formation. These rocks are more resistant to erosion than those in the surrounding areas, which fact has resulted in the generally steeper and more rugged topography in this area.

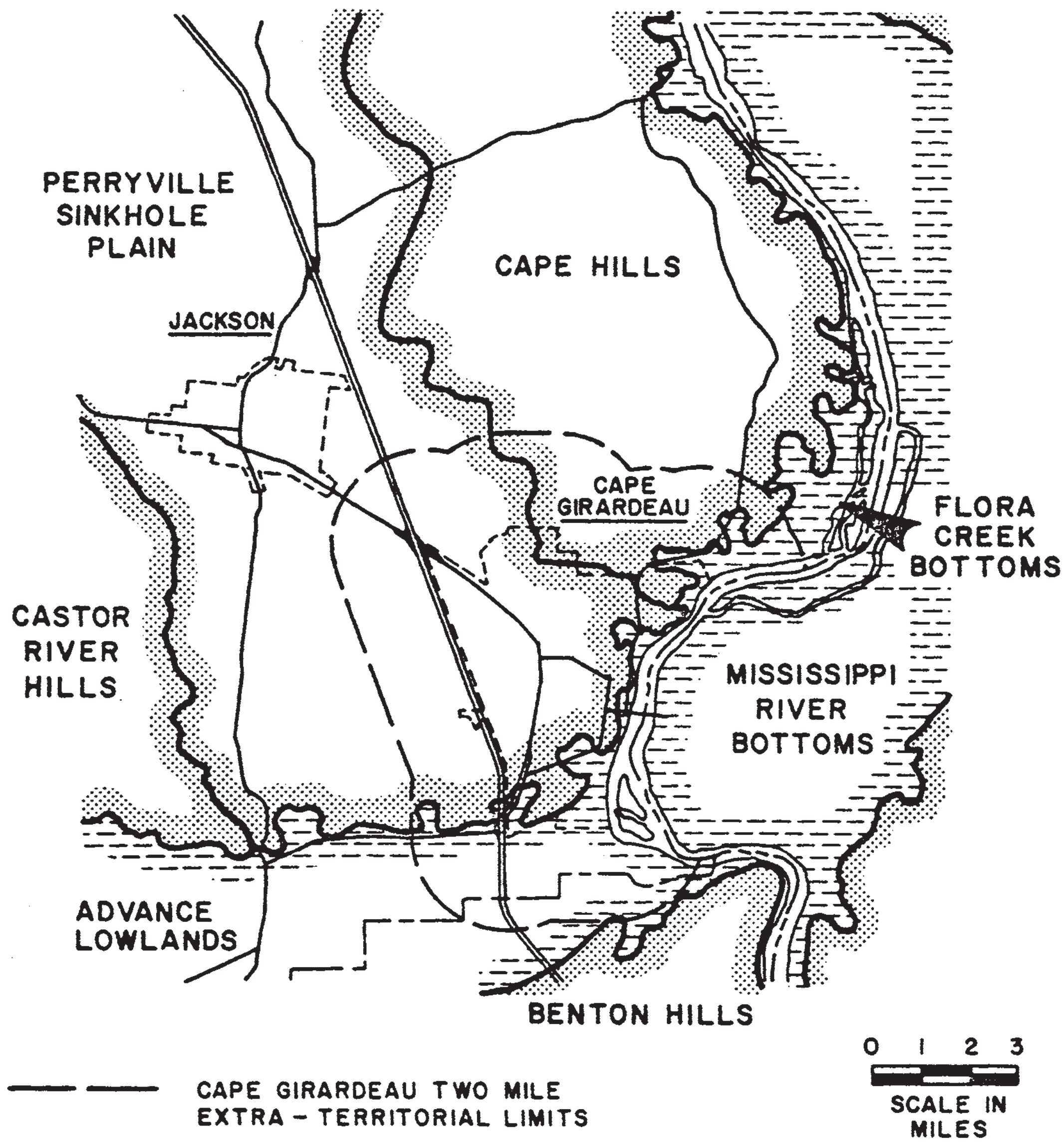
The Cape Hills division contains the highest elevations found in the area, as previously mentioned under the discussion on topography, and it also encompasses the area characterized by slopes exceeding 15% mentioned in the discussion on slopes.

A small portion of this division lies within the northeastern limits of the City of Cape Girardeau, and some development is presently occurring in the area immediately north of the City. However, this area should be eliminated from future consideration for extensive development because of the topographic, geologic, and drainage limitations present.

The central portion of the Cape-Jackson area lies within the physiographic division referred to as the Perryville Sinkhole Plain. This division is named for its typical development in the vicinity of Perryville, Perry County. Bretz, (1965, p. 125) originally referred to the type area as the Perry County Sinkhole Plain, but did not discuss any extension of the area beyond Perry County.

EXHIBIT NO. 12

PHYSIOGRAPHIC DIVISIONS



— — CAPE GIRARDEAU TWO MILE EXTRA-TERRITORIAL LIMITS

- - - - CITY LIMITS

SOURCE: BRETZ, J.H., 1965, GEOMORPHIC HISTORY OF THE OZARKS OF MISSOURI: MO. GEOL. SURVEY, VOL. 41; GROHSKOPF, J.G., 1955, SUBSURFACE GEOLOGY OF THE MISSISSIPPI EMBAYMENT OF SOUTHEAST MISSOURI: MO. GEOL. SURVEY, VOL. 37.

The Perryville Sinkhole Plain extends westward from the Cape Hills and is characterized by generally lower, evenly rolling topography. The division encompasses the smoothest topography found in the uplands of the County. Elevations in this area generally range between 400 and 600 feet and slopes are mixed and vary from nearly vertical to less than 5%. However, most of the area of less than 5% slope is found in the flood-plains in this division.

Most of the Sinkhole Plain is underlaid by limestones and dolomites of the Dutchtown, Joachim, Rock Levee (now Pecatonica, editor), Plattin, Decorah, and Kimmswick Formations. These rocks are characterized by solutional features developed through solution of the carbonate bedrock by groundwater. These solutional features include pinnacled bedrock surfaces, enlarged joints (cracks in the rocks), cave systems, and sinkholes. Although sinkholes are not as common in the vicinity of Cape Girardeau as they are in northern Cape County and in Perry and Ste. Genevieve Counties, groups of sinks are present near Gordonville, between Dutchtown and Benton Hill Road, west of Stout Road, and west of Jackson. The solutional features together constitute what is commonly referred to as a karst terrane.

A small portion of the Cape-Jackson area located southwest of Jackson lies within the physiographic division referred to as the Castor River Hills. Although elevations in this area are similar to those in the Sinkhole Plain, the topography here is more steeply rolling and slopes exceeding 15% dominate. This area also lacks the widespread development of solutional features found in the Sinkhole Plain, although such features are present locally.

The area to the south of the bluff line along Missouri 74 lies within the division known as the Advance Lowlands subsection of the Southeastern Lowlands. The area was named by C. F. Marbut in 1902 (Grohskopf, 1955, plate VII). A small section of this area east of Interstate 55 has also been referred to as the Black Land Bottoms (U.S.G.S., Cape Girardeau 7 1/2-minute quadrangle).

The terrain in the lowlands is essentially flat and featureless. Elevations generally range between 320 and 350 feet and only isolated areas with slopes exceeding 5% are present. The lowland area is underlaid by alluvium (silt, sand, and gravel) deposited by the Mississippi River as it flowed through this area prior to its diversion through the gap at Thebes. This event probably occurred about 14,000 to 15,000 years age, during the later stages of Pleistocene glaciation, and was the result of a huge torrent of water (Kankakee Flood) released in northern Illinois by melting glaciers (Willman and Frye, 1970, p. 35 - but see paper by R. Knox on Thebes Gap which follows, editor). Thin, waterlaid deposits in the loess at Cape Girardeau and about 50 feet above the present floodplain indicate that the water of the Mississippi River was at least 50 feet higher at that time (Ibid.).

The only large area of Mississippi River Bottoms in Cape Girardeau County is located between Bainbridge and Cape Girardeau. This area is referred to as the Flora Creek Bottoms. Elevations and slopes in this area are similar to those in the lowlands.

An important feature which crosses the physiographic divisions of the uplands is Oak Ridge. This ridge crosses the county in a northwest-southeast direction, extending from the northwest corner of the county to the northern edge of Cape Girardeau. The ridge constitutes the major drainage divide in the county and separates the eastward flowing streams which empty directly into the Mississippi from the southward flowing streams which empty into the Headwater Diversion Channel and the Dutchtown Ditch (Cape La Croix Creek is included in the southward flowing drainage although it has been diverted and now empties directly into the Mississippi). The crest of Oak Ridge generally lies at elevations above 600 feet and it exceeds 700 feet locally in the Cape Hills area.

Stratigraphy

Editor's note: Exhibit No. 18 is excerpted from Kent Bratton's Report, and illustrates a composite column for the Cape Girardeau area as then known. Rock Levee formation would be roughly equivalent to the Pecatonica formation mentioned elsewhere in this guide book. Bratton's narrative on stratigraphy is not included here. A narrative composite section follows this report.

Structural Features

The geologic structure, or the attitude of the rocks, in an area can affect many facets of urban development. For example, groundwater availability, mineral resources, and foundation stability can all be affected by the location and proximity of a fault or fault zone.

Exhibit No. 20 presents diagrammatic cross-sections that illustrate the attitude of the rock layers along the line of sections. The east-west section indicates the general northeastward dip of the bedrock units in the area and the relationships of the surface to the rocks beneath it. The north-south section illustrates the offsetting of the bedrock units along the Jackson Fault (see following paragraphs and exhibits). It must be stressed, however, that the vertical exaggeration used in the cross-sections does not give a true impression of the attitude or dip of the bedrock in this area. As a whole, the bedrock units dip or incline to the northeast at angles usually less than 1 or 2 degrees, and this fact needs to be considered when viewing the cross-sections.

Faults are perhaps the most spectacular structural feature in the area and the distribution of known faults is shown in Exhibit No. 21. It must be pointed out that the exact locations of the fault lines are not known in some areas and therefore the map indicates only the general locations of these features. Also, other faults probably exist in the area but have not yet been detected.

The largest known fault has been named the Jackson Fault (Gealy, 1955, p. 160). This fault traverses the area from near the Missouri 34-72 junction, west of Jackson, to the Mississippi River near the northeastern corner of Cape Girardeau. Evidence indicates that the north side of this fault has been downthrown approximately 200 feet in relation to the south side.

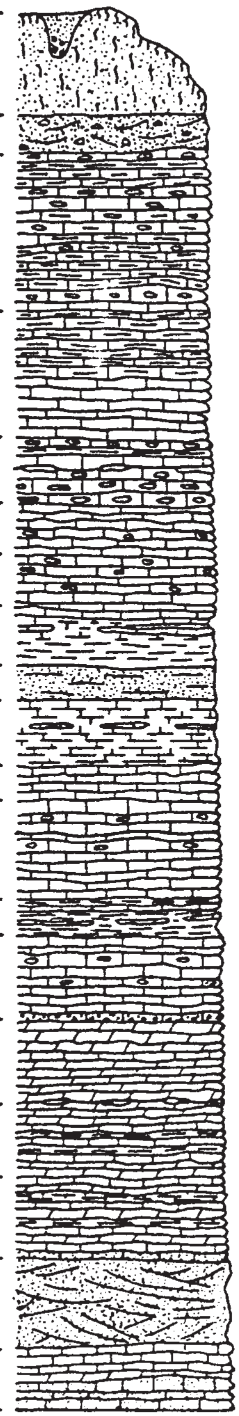
The only other fault in the area that has been named is the Cape Girardeau Fault in the eastern part of the City, with a displacement of approximately 40 feet (McCracken, 1971, p. 17).

None of the faults in the immediate vicinity of Cape Girardeau are known to be seismically active at the present time. However, the City is only 25 to 30 miles from the epicentral line of the New Madrid area earthquakes. The New

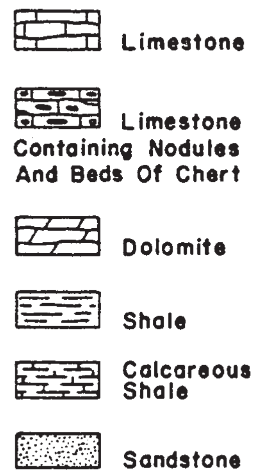
EXHIBIT NO. 18

GENERALIZED GEOLOGIC COLUMN

PRINCIPAL ROCK TYPES	THICKNESS (FEET)	NAME
Silt, Sand, Clay & Gravel	0-150	Loess, Alluvium, & Residual Soil
Sand & Gravel	0-5	"Lafayette" Fm.
Cherty Limestone, Limestone, & Shale	± 300	Bailey Fm.
Limestone & Shaly Limestone	30-160	Bainbridge Fm.
Limestone & Cherty Limestone	20-60	Sexton Creek Fm.
Limestone	± 20	Edgewood Fm.
Limestone	25-35	Girardeau Fm.
Shale & Limestone	60-85	Orchard Creek Fm.
Sandstone	4-20	Thebes Fm.
Shale & Limestone	10-60	Maquoketa Fm.
Limestone	7-15	Cape Fm.
Limestone	75-140	Kimmswick Fm.
Limestone & Shale	10-30	Decorah Fm.
Limestone	± 420	Plattin Fm.
Limestone & Dolomite	± 270	Rock Levee Fm.
Dolomite, Limestone, & Shale	± 175	Joachim Fm.
Limestone & Dolomite	85-170	Dutchtown Fm.
Sandstone	50-195	St. Peter Fm.
Dolomite & Sandstone	400-480	Everton Fm.



GEOLOGIC SYMBOLS



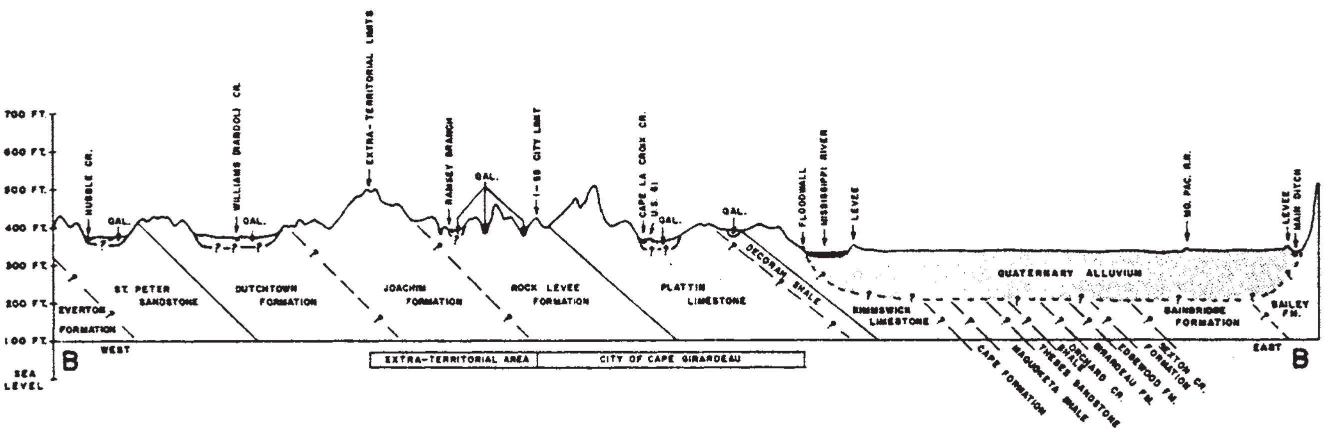
Source:

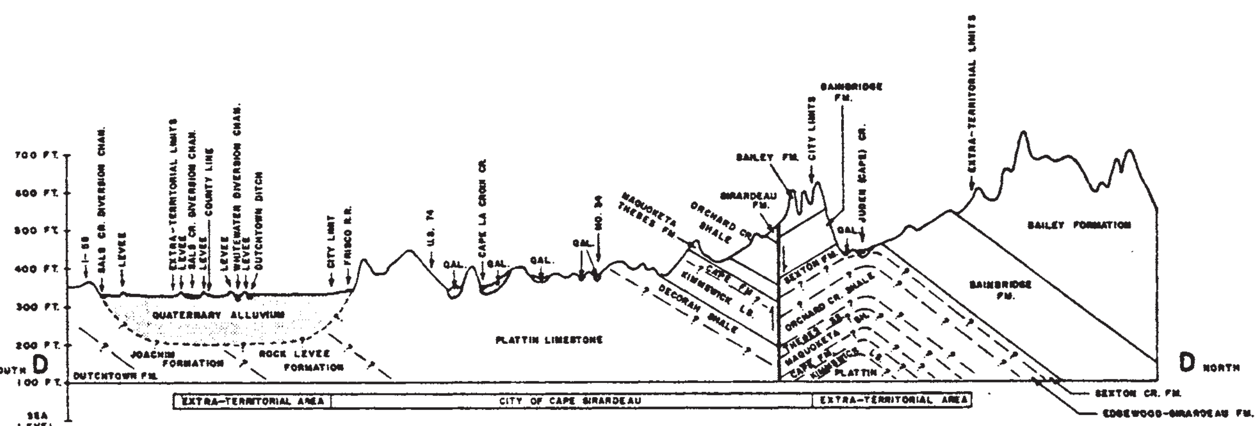
Gealy, 1955;
Koenig, Ed., 1961

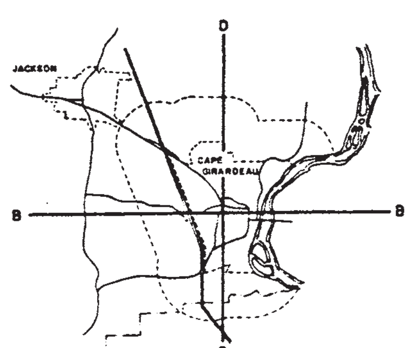
EXHIBIT NO. 20

GEOLOGIC CROSS-SECTIONS:

CAPE GIRARDEAU – JACKSON URBAN AREA







LINES OF CROSS SECTIONS

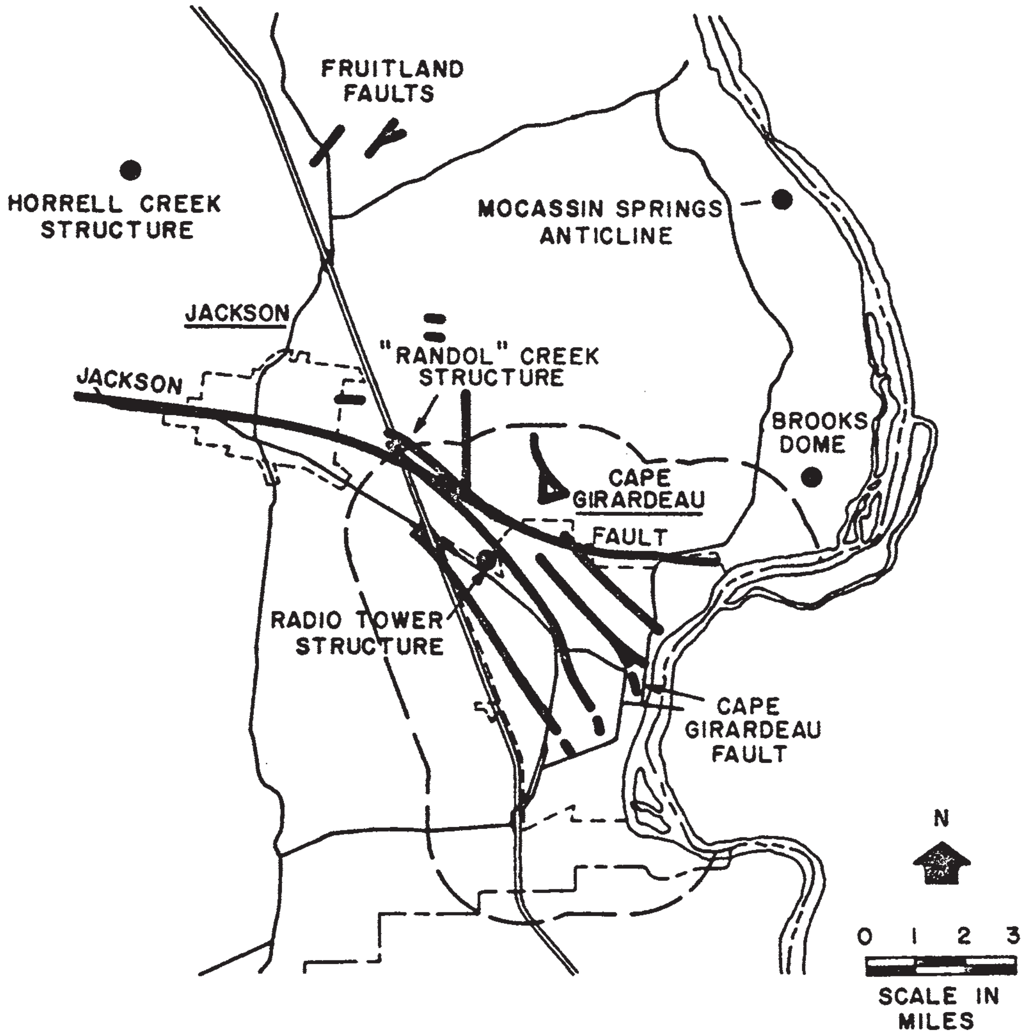
GENERALIZED GEOLOGIC COLUMN

QUATERNARY ALLUVIUM (QAL.)
BAILEY FORMATION
BAINBRIDGE FORMATION
SEXTON CREEK LIMESTONE
GIRARDEAU LIMESTONE
ORCHARD CREEK FORMATION
MAQUOKETA AND THEBES FORMATIONS
KIMMSWICK LIMESTONE
PLATTIN LIMESTONE
ROCK LEVEE – JOACHIM – DUTCHTOWN FORMATIONS
ST. PETER SANDSTONE
ST. PETER – EVERTON FORMATIONS

NOTE:
VERTICLE EXAGGERATION APPROX. 25 TIMES. DIP OF FORMATIONS IS EXAGGERATED AS A RESULT OF THE EXAGGERATION OF THE VERTICAL SCALE.
GEOLOGIC COLUMN IS ARRANGED WITH OLDEST FORMATIONS AT THE BOTTOM AND YOUNGEST FORMATIONS AT THE TOP.
CROSS SECTIONS DEVELOPED FROM A GEOLOGIC MAP PREPARED BY JOHN R. GEALY, 1955.

EXHIBIT NO. 21

FAULTED AREAS AND STRUCTURAL FEATURES



CAPE GIRARDEAU TWO-MILE EXTRA-TERRITORIAL LIMITS

CITY LIMITS

GENERAL LOCATION OF KNOWN FAULT

SOURCES: GEALY, J.R., 1955, GEOLOGY OF CAPE GIRARDEAU AND JONESBORO QUADRANGLES, SOUTHEASTERN MISSOURI:
IRA SATTERFIELD, MO. GEOL. SURVEY, PERSONAL COMMUNICATIONS
McCRACKEN, M. H., 1971, STRUCTURAL FEATURES OF MISSOURI; MO. GEOL. SURVEY, REPT. INV. NO. 49.

Madrid area is seismically active at the present time and a major earthquake along this lineament could cause considerable damage in the Cape Girardeau area (Exhibit No. 22). This possibility has been taken into consideration in the design of the new St. Francis Hospital being constructed in the City.

It is probable that most of the known faults in the Cape Girardeau area present little danger in regard to earthquakes and for most small structures. However, large, expensive structures, particularly those that are publicly financed, or that may contain large numbers of people should not be built over a fault, especially one with a large displacement. Where the presence of a fault is suspected, detailed on-site investigations should be carried out by qualified personnel, in coordination with the Missouri Geological Survey, to determine if a substantial hazard may exist.

Other structural features which exist in the area include the upward known as Brooks dome (Gealy, 1955, p. 164) and a number of ancient sink structures. The largest of the sink structures is referred to as the Radio Tower Structure (Gealy, 1955, P. 166). These structures have resulted from the collapse of overlying beds into large sinks at some time in the geological past.

Mineral Resources

All of the mineral resources presently produced in the Cape Girardeau area, and all potential resources, are non-metallic or industrial minerals. These include limestone, clay and shale, sand and gravel, and silica sand.

High-quality limestone is the most important mineral resource in the area. Such limestone occurs in the Kimmswick, Plattin, and Rock Levee (Pecatonica, editor) Formations which underlie a belt extending through the central part of the county and much of the City of Cape Girardeau (Exhibit No. 32).

At the present time only the Plattin and Rock Levee Formations are quarried in the area. The Marquette (now Lone Star, editor) Cement Company, located at the southern edge of Cape Girardeau, utilizes Plattin Limestone and alluvial clays for the production of portland, masonry, and specialty cements. The Southeast Missouri Stone Company, also at the southern edge of the City, produces crushed limestone from the Plattin and Rock Levee.

The Plattin limestone is suitable for cement manufacture and for most uses for crushed stone. The beds of the formation vary somewhat in purity, the calcium carbonate content ranging from 70 to 98%. The unit is approximately 500 feet thick in the Cape Girardeau area.

The Kimmswick Formation is generally purer than the Plattin, with a calcium carbonate content generally ranging between 95 and 99% (Missouri Geological Survey, 1967, p.131). This formation was previously used in the manufacture of lime at Cape Girardeau (1840-1925 approximately) and also as a marble for building purposes. Production of this type could be realized in the future. The Kimmswick ranges from 75 to 140 feet thick in the Cape area.

The Rock Levee Formation consists predominantly of limestone with interbedded dolomite. Its calcium carbonate content ranges up to 75% (Missouri Geological Survey, 1967, p. 131) and it is as much as 270 feet thick

EXHIBIT NO. 22

SIESMIC HISTORY AND RISK IN SOUTHEAST MISSOURI AND VICINITY

SEISMIC RISK ZONES

ZONE 1: EXPECTED MINOR EARTHQUAKE DAMAGE

ZONE 2: EXPECTED MODERATE DAMAGE

ZONE 3: MAJOR DISTRUCTIVE EARTHQUAKES MAY OCCUR

SOURCE: E.S.S.A., COAST AND GEODETIC SURVEY, 1969.

DAMAGING EARTHQUAKES FROM EARLIEST HISTORY THROUGH 1970

INTENSITY
- ● VII—VIII
- ■ VII—IX
- △ X—XII

SOURCE: N.O.A.A., UNITED STATES EARTHQUAKES 1970 in the Cape Girardeau area. (Note: The area underlaid by the Rock Levee could not be determined on the basis of existing maps and it is therefore not shown in Exhibit No. 32. However, it would cover the area immediately west of the High-Quality Limestone area show, for an unknown distance.)

Sand and gravel are important resources in any urban area because of their primary use as concrete aggregate and for road surfacing. At one time, the Cape Girardeau-Jackson area had relatively abundant deposits of gravel in the upland stream beds of the area. However, these have largely been depleted and major users are being forced to rely on more expensive quarry stone. The only producer of sand in the area at the present time is the Cape Girardeau Sand Company. This company produces sand from the alluvial materials of the Mississippi River.

Local sources of sand, gravel, and crushed stone are essential because of the relatively low unit value of these materials and the high cost of transporting them. This fact should be taken into consideration in planning for the area's development and, where possible, potentially important sources of these materials should be protected.

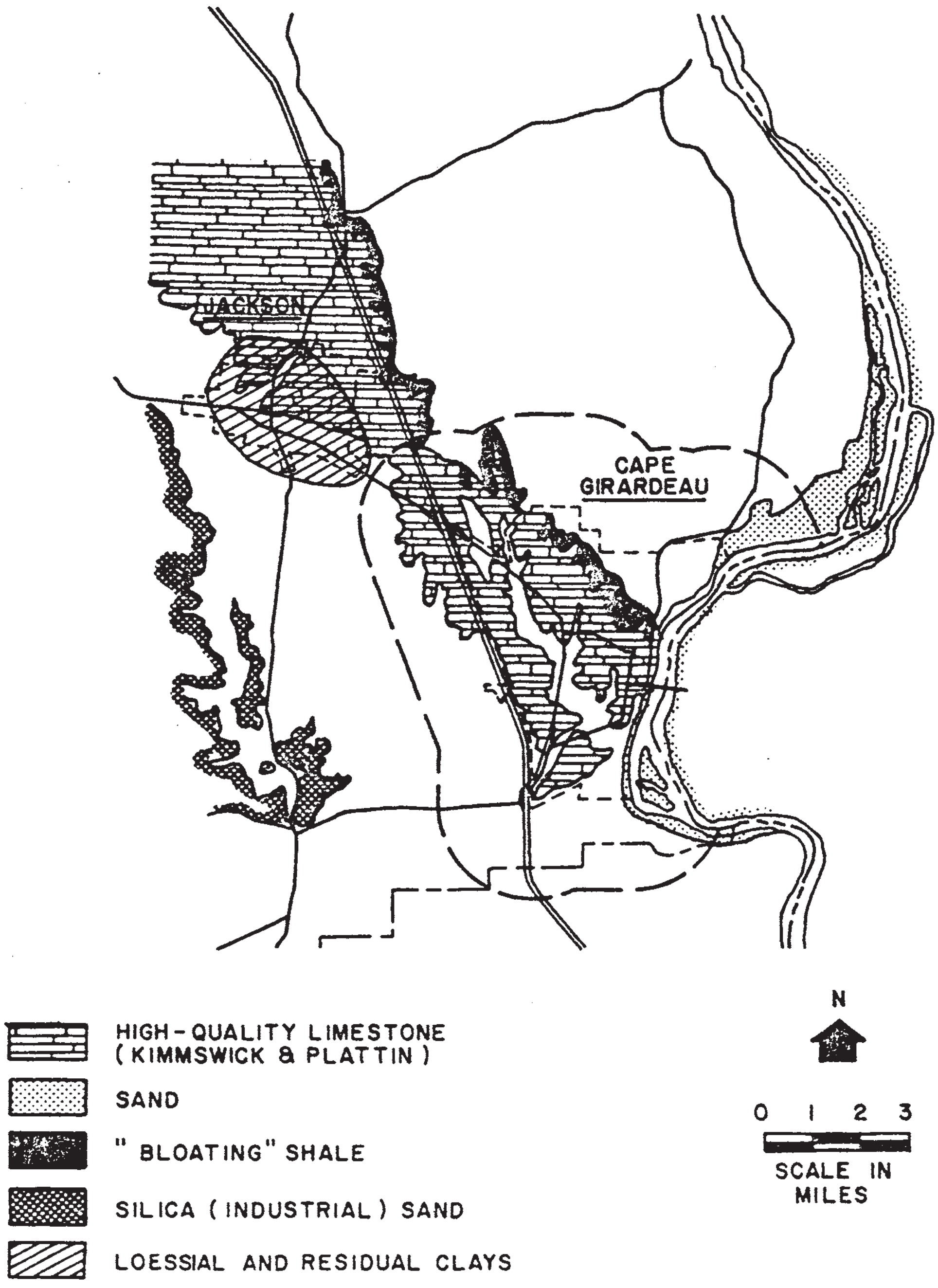
The Cape Girardeau-Jackson area also contains deposits of loessial and residual clay that are suitable for the production of ceramic products. At the present time, the only producers of these materials are located at Jackson. Kasten Clay Products, Inc., produces pressed brick and the Ceramo Company, Inc., produces red clay flower pots. Similar deposits may be present in the area, but more detailed investigations will be required to locate and evaluate them.

The Cape Girardeau area also contains deposits of shale which are suitable for the production of light-weight aggregate, such as might be used in the production of Haydite blocks (Herold, et at., 1958, p. 14 and 37). The shale occurs in the Maquoketa Formation, but detailed investigations to delimit the outcrop area of this material and its overall quality have not been undertaken.

Another resource that has not been produced in the area is the silica, or industrial, sand of the St. Peter Formation. This unit is exposed in the vicinity of Gordonville and Dutchtown, and west of Jackson. Two tests of the unit in the vicinity of Dutchtown show that it has a silica content of more than 99% and that its location is suitable for quarrying (Missouri Geological Survey, 1976, p. 208-212). The purity of this sand and its uniform grain size make it suitable for the manufacture of glass, for molding sand, as a grinding and polishing material, and as a filtering material, among other potential uses.

EXHIBIT NO. 32

MINERAL RESOURCES



Composite Stratigraphy of the Cape Girardeau Area

Editor's Note: The following narrative stratigraphic column was compiled by Ray Knox from several different sources, the most important being quadrangle geologic maps of the area by Dewey H. Amos. It is arranged in order from oldest to youngest. The Tertiary units are found only in the Crowley's Ridge, south and southwest of Cape Girardeau. Specific stratigraphic information on the Plattin and Pecatonica follows in the report by Childers, et al.

Sedimentary rock formations ranging in age from Middle Ordovician dolomites and sandstones to Quaternary alluvium are found in local outcrops in the Cape Girardeau area. A description of each unit follows:

Ordovician System

Everton formation 400'-480' thick	Dolomite, sandstone, and shale: Dolomite, light- to medium gray, fine grained to finely crystalline, medium- to thick bedded; most beds sandy and thinner beds are generally argillaceous; local algal reef structures and bluish-gray to dark-gray chert nodules. Sandstone, white to light-yellowish- and light-reddish-brown, chiefly of medium subrounded, frosted quartz grains; generally friable with dolomitic cement. Shale, greenish-gray dolomitic, occurs as partings and thin sets of interbeds.
St. Peter Sandstone 50'-195' thick	Sandstone, white to very light brown, weathers light to medium brown to medium gray; medium to fine grained; rounded and well-sorted quartz grains commonly frosted. Sandstone is friable but commonly case-hardened and locally orthoquartzitic; it is generally massive to thick-bedded, commonly cross-bedded and ripple-marked. Basal contact is poorly exposed. Unconformable on underlying Everton Formation.
Dutchtown Formation 85'-170' thick	Dolomite, sandstone, and shale: Dolomite, medium- to very dark gray and dark-brown, finely granular, sandy to silty, medium- to thin-bedded; freshly broken surfaces commonly have petroliferous odor. Sandstone, medium- to dark brown and brownish gray, fine-grained, very dolomitic, medium bedded. Shale greenish-gray, chiefly as thin partings. Unconformable on underlying St. Peter Sandstone.

Joachim Dolomite c 175' thick	Dolomite, sandstone, and subordinate shale. Dolomite, light- to medium brown and light- to medium-gray, commonly weathers to yellowish- to brownish-buff; fine grained to finely crystalline, thick to medium bedded, some beds argillaceous. Limestone, medium- to dark-gray and light- to medium-brown, finely crystalline to sublithographic. Shale, green to greenish-gray, dolomitic. Unconformable on underlying Dutchtown Formation.
Pecatonica Formation c 270' thick	Limestone, dolomite, and shale, in part interbedded. Limestone, medium- to light-gray and light- bluish-brown, finely crystalline to sublithographic; some beds dolomitic and contain a few scattered light-tan and black chert nodules in upper part of unit; some fucoidal structures. Dolomite, medium- to light-brown, fine-calcitic. Shale, medium-gray, occurs as partings and thin interbeds. Ostracods and brachiopods in a few beds in upper part of formation. Conformable with underlying Joachim Dolomite.
Plattin Limestone c 420' thick	Limestone, dolomite, and shale. Limestone, light- to medium-brown and light-gray to medium-brownish-gray, fine-grained to sublithographic; thick to medium bedded, some thin-bedded, a few wavy bedding planes; some beds dolomitic; oolitic limestone conglomerate near base of unit; rarely fossiliferous; contains sparse, light-brown chert nodules. Dolomite, light- to medium-brown and medium-brownish-gray, fine-grained, calcitic. Shale, medium- to dark-gray, calcareous, occurs as sparse thin interbeds. Sinkholes common in unit; conformable with Pecatonica Formation.
Decorah Formation 10'-30' thick	Shale and limestone, in part interbedded. Shale, light- to medium-brown and medium-greenish-gray, very calcareous. Limestone, dark- to medium-gray, finely crystalline, argillaceous, fossiliferous. Unit unconformably overlies Plattin Limestone.
Kimmswick Limestone 75'-140' thick	Limestone, white to very light gray, some pinkish-gray, coarsely crystalline, thick to massive bedded; contains abundant fossil fragments; locally crossbedded; many beds weather with pitted surfaces. Unit is unconformable on Decorah Formation.

Cape Formation 7'-15' thick	Limestone, medium- to dark-gray, coarsely to medium crystalline, thick to medium bedded; slightly argillaceous in upper part, fossiliferous. Unit is unconformable on Kimmswick Limestone.
Maquoketa Formation	
Unnamed Shale Mbr. 10'-60'	Shale and limestone. Shale, light- to medium-brown and greenish-gray, calcareous. Limestone, light-bluish-gray, fine-grained, argillaceous; occurs as thin beds and nodules. Unconformable on Cape Limestone.
Thebes Sandstone Mbr. 4'-20' thick	Sandstone. Grayish-brown and light to medium brown; dull green tint common; fine to very fine grained, thick to medium bedded, less commonly thin bedded; argillaceous, especially the thinner beds; commonly slightly calcareous; conspicuously porous. Unit slightly unconformable on underlying Unnamed Shale.
Orchard Creek Shale Mbr. 60'-85' thick	Shale and limestone, in part interbedded. Shale, light-brown to greenish-brown and medium-gray, very calcareous. Limestone, light- to medium-gray, finely crystalline, medium- to thin-bedded; some beds discontinuous, argillaceous, in part fossiliferous. Basal contact at places represents sedimentation break but at other places is gradational.
Girardeau Limestone Mbr. 25'-35' thick	Limestone and shale, in part interbedded. Limestone, light- to medium-gray, sublithographic to very finely crystalline, thin- to medium-bedded, in part argillaceous. Shale, light- to medium-yellowish-brown, calcareous, as partings and thin beds. Conformable on underlying Orchard Creek Shale.
Silurian System	
Sexton Creek Limestone 20'-60' thick	Limestone and chert, commonly interbedded. Limestone, light-brown to light-yellowish-brown, some light-gray to light-brownish-gray, micritic to finely crystalline, rarely medium-crystalline, chiefly thin-to medium-bedded, less commonly thick-bedded; small fossil fragments, chiefly crinoids. Chert, light- to medium-bluish- weathered limestone blocks. Regional unconformity at base of unit.

Bainbridge Formation	
St. Clair Limestone Mbr. 10'-30'	Limestone. Pinkish-red to light-pinkish-gray, micritic to medium crystalline, thick-bedded, fossiliferous. Basal contact unconformable on Sexton Creek Limestone.
Moccasin Springs Mbr. 20'-130'	Limestone and shale. Generally mottled brick-red, reddish-green, and greenish-gray, less commonly purple. Limestone, very fine-grained to fine-grained, thin- to medium-bedded, less commonly thick-bedded, argillaceous; has earthy luster; some beds fossiliferous. Shale has earthy luster and some is calcareous. Unit is conformable on St. Clair Member.
Devonian System	
Bailey Formation c. 300' thick	Shale and chert. Shale, red, poorly fissile, some slightly calcareous, weathers to very plastic clay. Chert, white to grayish-white, chalcedonic, semi-opaque, commonly medium-bedded, weathers to small, angular, tripolitic fragments. Unit is conformable on Moccasin Springs Member of Bainbridge Formation in southeastern Missouri.
Cretaceous System	
McNairy Formation c. 50' thick	Sand, sandstone, and clay, in part interbedded. Sand, very light-brown to light-yellowish-brown, locally white or orangish-brown; fine to medium subangular quartz grains; locally argillaceous, rarely micaceous. Sandstone, white and light-brown to light-yellowish-brown; outer surfaces weather light- to medium-gray or medium-brown; generally friable. Clay, light-gray and very light- to medium-brown, as beds and scattered blebs in sand. Unconformity at base.
Owl Creek Formation 0'-10' thick	Clay, dark bluish-gray on fresh exposures to yellowish-brown on weathered surfaces. Massive, micaceous, fossiliferous, commonly glauconitic. Ammonites, small echinoids, and the gastropod Turretella seen in some locations. Some zones calcareous or pyritized. Unconformable on underlying McNairy Formation.

Tertiary System

Clayton Formation 0'-10' thick	Clay and sandy clay, distinctive greenish-gray. Fossiliferous, calcareous, glauconitic. Varying amounts of limonite. Unconformable on underlying Owl Creek Formation.
Porters Creek Formation c 200' thick	Clay, dark gray to almost black when wet. When dry, spills with a characteristic conchoidal fracture and is white to very light gray. Massive, homogeneous, small amounts of mica and gypsum are disseminated throughout the formation. Fine-grained, white sand and mica are concentrated along some parting planes. Unconformity at base.
Ackerman Formation 0'-100' thick	Clay, light-gray to brown, silty, slightly lignitic. Glauconite is locally present at the base. The upper 6 or 8 feet is very plastic and bright red or yellow in color. In places, the Ackerman-Porters Creek contact is marked by a lenticular sandstone body. Unconformity at base.
Holly Springs Formation 1'-250' thick	Sandstone, sandy clay, clay, and gravel. Commonly crossbedded. Variably sorted; well to poorly sorted. Sandstone color near white when fresh, orange to red when weathered. Clay erratically distributed as thin beds and lenses. Clay is multicolored and ranges from white, gray, yellow, red, lavender, green, brown, and black. Base of Holly Springs commonly contains a bed of rounded, highly polished, black gravel. Unconformity at base.

Tertiary/Quaternary Systems?

Mounds Gravel 0'-15' thick	Gravel and subordinate sand, silt, and clay, in part mixed; local crude bedding and crossbedding. Gravel, chiefly of light- to medium-brown to yellowish-brown and some light-gray chert as poorly sorted subangular to subrounded pebbles generally less than 3 in. in diameter but subrounded to rounded white quartz pebbles also are common; a few pebbles are highly polished; in places, gravel is cemented with ferruginous oxides and hydroxides; matrix composed of silt, clay, and poorly sorted coarse to medium quartz sand. Sand, reddish- to medium-brown, some purplish-brown; poorly sorted; medium to less commonly coarse or fine, subangular to angular quartz. Silt, reddish-brown, commonly micaceous. Unconformity at base.

Quaternary System

Pleistocene Series

Loess 0'-80' thick	Silt and clay, intermixed, light- to yellowish-brown to light-reddish-brown, nonbedded; silt is chiefly quartz; local calcareous concretions; deposit blankets upland surfaces. Unconformity at base.

Pleistocene and Holocene Series

Fluvial and Fluviolacustrine Deposits 0'-200' thick	Silt, clay, sand, and gravel, in part intermixed and interbedded; Silt, light-gray and light-grayish-brown, clayey, locally sandy; partly derived from local loess deposits; constitutes much of the alluvium underlying the major lowlands and along larger streams. Clay, light- to medium-gray or very light-yellowish-brown, commonly silty; in part thinly laminated; dominant lithology of the fluvio-lacustrine deposits. Sand, light-brown to light-yellowish-brown, moderately sorted fine to medium quartz grains, in part silty; common along streams in areas underlain by the McNairy Formation. Gravel, poorly sorted, angular to subrounded sandstone and chert fragments locally derived from the Mounds Gravel, McNairy Formation, and residuum of Ordovician units.

Road Log for Friday Afternoon Field Trip
Lone Star Cement Plant and Quarry Operations

Miles Interval	Miles Elapsed	
	0.0	Leave Holiday Inn. Turn left (west) toward Interstate 55.
0.2	0.2	Turn left (south). Merge onto I-55.
0.2	0.4	Mile marker 96. Throwed roll sign!

The Valley of Ramsey Creek. Notice the broad, flat valley of Ramsey Creek. It is one of many examples of misfit streams in this area. The streams are far too small in proportion to their valleys. Ramsey Creek was probably ponded one or more times during periods of flooding of the Mississippi. The shape and location of this valley suggest that most of these episodes occurred before the Mississippi abandoned it's former course through Black Land Bottom, the Drum and Advance Lowlands, and southwestward past Poplar Bluff.

2.1	2.7	Bridge over Ramsey Branch.
0.1	2.8	Exit I-55.
0.3	3.1	Lowlands of former channel of Mississippi in view ahead.
0.2	3.3	Intersection. Turn left (east) on State Highway 74. Drive under I-55 and continue east.
0.2	3.5	Continue east on unsigned blacktop. For the next mile or so, you are paralleling the former course of the Mississippi.

Black Land Bottom. As we drive eastward from our exit of Interstate 55 toward Lone Star, you will notice a distinct difference between the terrain to your left and your right. The landscape to the left is carved by streams and mass wasting upon Ordovician carbonates. To your right, the former course of the Mississippi River can be seen. This easternmost segment of the Advance Lowland is locally called Black Land Bottom. On the south side of this abandoned floodplain you can probably see the Benton Hills, the northeasternmost extension of Crowley's Ridge.

1.2	4.7	Natatorium on left. We will return here for a cool one or two as our last stop of the day!
0.3	5.0	Lone Star Cement visitors gate. Turn right.

At the Lone Star Plant the group will be divided into smaller groups to tour the quarry and plant. Descent into the quarry will be by bus. A booklet on the operation of the plant will be provided for each trip participant. Additional detailed information follows in the article by Childers, Aukeman, and Vontress. Please note that while on the plant grounds, all visitors must wear hardhats. Your cooperation in this is appreciated.

0.3	5.3	Exit Lone Star lot. Turn left (west). Park at Natatorium lot on right.

Mining and Cement Production at Lone Star Industries Cape Girardeau Plant

Andy Childers, Fred Aukeman and John Vontress
Lone Star Industries, Cape Girardeau Plant

Introduction

The mining and manufacturing operations of Lone Star Industries are located at the southern city limit of Cape Girardeau, Missouri. The quarry and cement production facility are situated at the intersection of an abandoned river channel of the Mississippi River, the present active Mississippi River and outcroppings of Ordovician age limestones. These limestones are classified as high calcium limestones and are well suited for Portland cement manufacturing.

Geologic Relationships

The Cape quarry lies at the edge of the Ozark highlands, Illinois basin and the Mississippi Embayment. Exposed rocks of economic interest in the local quarry area are Ordovician age, Plattin and Pecotonica formations which dip gently into the Illinois Basin. Clay filled sinks and solutional cavities occur in the upper forty feet of the Plattin and these in turn are overlain by Pleistocene loess and sand deposits. The general stratigraphic section of the quarry area is shown in Figure 1.

Within the quarry, the Plattin formation consists of mudstones, wackestones, and packstones with some shale in the basal section. It is conformable to the underlying Pecotonica formation which consists of interbedded mudstones and wackestone that grade from high magnesium limestones to dolomites. Since the dolomite to limestone ratio increases with depth, the use of this unit is limited to its upper 150 foot for cement production. Table 1 shows specific lithologies with depth for the quarry.

Quarry Structures

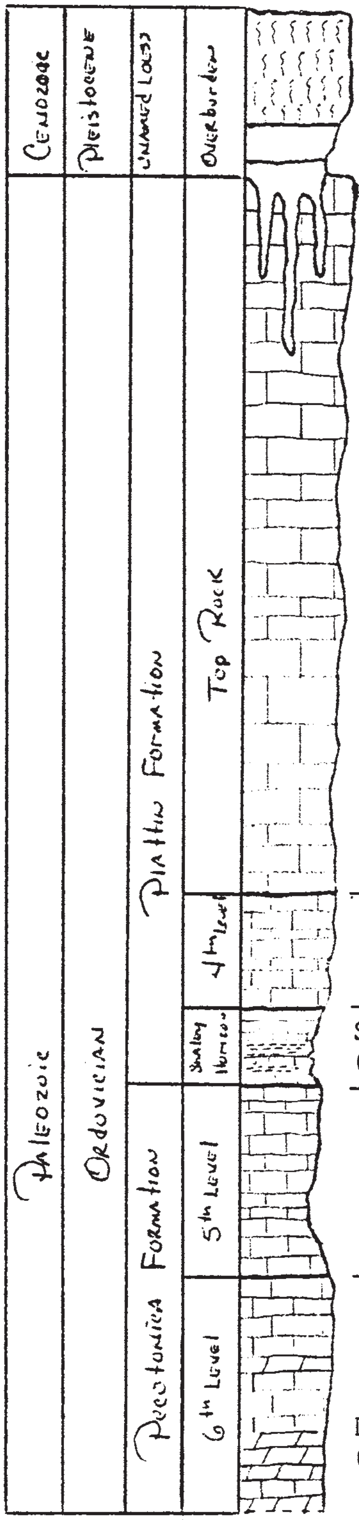
A major wrench fault transects the entire quarry on the major exposed east face. Based upon analysis of minor drag folds this fault is interpreted as a right lateral wrench fault with a component of dip slip movement of normal sense. The fault is imbricated with the development of two to five glide blocks in the plane of the fault. Strikes taken on the fault plane average N 80°W with a 75°-89° dip south. Large slickensides are present with amplitudes up to one foot. Minor anticlinal and synclinal fold development is present in individual fault slices.

A small minor normal fault which strikes N 85°E and dips 70°N occurs in the fifth level (Pecatonica) with one half meter displacement. Other large scale fractures which occur in the quarry exhibit minor horizontal movement only.

Jointing is well developed throughout the quarry. Three major joint sets have been recognized with strikes N 50°W, N 35°E, and N 30° W.

Figure 1. LONE STAR INDUSTRIES
CAPE QUARRY

GENERAL STRATIGRAPHIC SECTION



MARKERS	LITHOLOGY
LOESS (high K_2O)	
UNCONFORMITY	
	Medium to dark grey mudstone, wackestones and crystalline carbonates. Thick to medium bedded, high calcium limestones.
	Medium to dark grey mudstone, wackstones, packstones. Medium bedded.
SHALEY HORIZON (high K_2O)	Thin bedded limestones and green shales.
	Dark grey mudstones, wacke-stones.Medium to thin bedded limestones.
DOLOMITE BOUNDARY (unuseable below)	Dark grey mudstones, wacke-stones that grade from lime-stones at upper portion to dolomites in rest of section Medium to thin bedded.

Table 1. Log of Lone Star Drill Hole D-55-3 Representative of Center of Existing Pit

Depth From	(Feet) To	Description
0	104	Limestone, dove colored, cryptocrystalline to medium crystalline. Mottled or banded with darker limestone between 31' to 32', 47' to 48',86' to 95', 100' to 102.
104	125	Limestone, alternating beds of dove colored and light gray cryptocrystalline stone.
125	135	Limestone, dark gray, cryptocrystalline.
135	160	Limestone, dove gray, banded, slightly crystalline, somewhat dolomitic.
160	165	Limestone, gray, mottled, slightly dolomitic.
165	177	Limestone, dove colored, mottled and banded with light gray limestone, slightly dolomitic.
177	220	Limestone, dove colored, crystalline. Banded with darker limestone between 202' to 203' and 216' to 220'.
220	223	Limestone, dark gray, cryptocrystalline, banded.
223	225	Limestone, light gray, cryptocrystalline.
225	228	Limestone, dark gray, cryptocrystalline, banded.
228	237	Limestone, dove colored.
237	238	Limestone, light buff.
238	241	Limestone, dove colored, lower part of unit banded, slightly dolomitic.
241	244	Limestone, dark gray, slightly dolomitic.
244	246	Limestone, light buff, slightly dolomitic.
246	257	Limestone, dove colored, banded zones, slightly dolomitic
257	258	Limestone, light gray, banded, slightly dolomitic.
258	259	Limestone, dark gray, banded, slightly dolomitic.
259	281	Limestone, alternating beds of light gray and dove colored stone, slightly crystalline, slightly dolomitic.
281	287	Limestone, dark gray, slightly dolomitic. Slightly broken at 281.
287	310	Limestone, alternating beds of light gray and dove colored stone, slightly crystalline, slightly dolomitic. Dark gray limestone between 306' and 307'.

Mining Methods and Rates

Mining rate:

The plant requires about 1.6 million tons of limestone per year for clinker production, and about 100,000 tons for masonry cement. This translates into about 34,000 tons per week (assuming two weeks down for maintenance), or about 7,000 tons per day.

Drilling:

Our primary drill hole is 6.5 inches in diameter, and the hole pattern is 22 feet spacing with 20 feet of burden. The face heights vary, but we are working toward a face of 50 to 60 feet in height. Since we are working against the quarry boundaries in a couple of locations, some of the faces are 125 to 150 feet in height.

Blasting Procedures:

We are using an ammonium nitrate - slurry mixture (ETI Pourvan) as the primary blasting agent. Holes less than 100' in depth are loaded with a solid column of explosives, using 1 lb. cast primers and Detaline (non-electric) downline. Holes over 100' are decked and double-delayed. Delay patterns are determined by the hole layout.

Many large boulders result from shooting in the old mined-out areas, so secondary blasting is a costly but necessary part of our operation. A hydraulic drill is used to drill 2 1/2" holes in the oversize rock, and ETI Tovex is used as the explosive.

Load and Haul Equipment:

Two Caterpillar 992C 13-yard loaders are used as the primary loading equipment, with a Cat 992B 10-yard loader as a stand-by. Two 50-ton Wabco and 2 55-ton Terex trucks are the primary haulage units with a 35-ton Wabco truck as the stand-by unit.

Load and Haul Procedures:

Since the muck piles are confined by narrow benches and short faces, it is usually necessary to operate the loaders at separate faces. This has some advantages and some disadvantages. Blending of rock in the quarry can be achieved by operating the loaders separately, but higher production rates result if it is possible to use them to "team load" the trucks.

Crushing:

The primary crusher is a Jeffery 627 Rockbuster impactor, with two impeller bars. The crusher is rated at 1,000 tons per hour, but with the generally poor breakage from blasting, our rate is about 750 tons per hour. We have achieved the 1,000 TPH or more on occasion, when crushing fourth or fifth level rock with a minimum of oversize in the pile.

Oversize rock from the screens is crushed by a small Portec jaw crusher, and goes directly to the storage pile.

Screening Equipment:

Rock from the primary crusher goes over screens with a 4 inch square opening in the top deck. Oversize rock is fed to the Portec reject crusher.

The screens are 8 x 20 feet Simplicity. One is a single deck screen which scalps the +4 inch rock, with the through rock going to the storage pile. The other screen is an 8 x 20 feet Simplicity with a top deck of 4 inch square hole plate, and a second deck of 1 inch mesh. The +4 inch material goes to the reject crusher, -4 inch to 1 inch material to the storage pile, and the -1 inch rock to the masonry rock pile.

Screening in this operation is not as critical as it might be in a commercial stone plant. The only requirements are that the top size be acceptable to the raw mill at the plant, and that the small size be acceptable to the masonry grinding finish mill.

Cement Production

Portland and Masonry cements are manufactured at this facility.

The raw materials are limestone, 86%; tripoli, 7%; flyash, 4%; and diaspore, 3%.

Materials are delivered or produced to arrive at the plant at -4 inch size. They are chemically proportioned and fed to the raw mill.

The raw mill dries and grinds the materials to a fineness of 75% -200 mesh. The ground raw meal is then airswept from the mill to a dust collector atop four raw mix silos. There the mix is removed and gravity fed into the silos.

This plant is unique in that the air and heat for drying and conveying the raw materials comes from the cooler on the pyroprocessing system. The air requirement for the raw mill exceeds the cooler capabilities; therefore, air is recycled from the raw mill dust collector vent stack as well.

The pyroprocessing system consists of three subprocesses.

The first is the preheating or precalcining which occurs in the preheater tower. In this process the material is heated to 1550°F. At this temperature the calcium carbonate decomposes into calcium oxide and carbon dioxide. The carbon dioxide is given off through the kiln stack as a gas. This sub-process utilizes a unique feature of preheating where solid feed, pulverized coal and preheated air are introduced into the tower. The combustion of the fuel takes place in suspension with the dispensed raw material in a swirl chamber. Sixty percent of our total fuel is introduced to the preheater tower in this manner.

The second subprocess is the rotary kiln where the precalcined materials are further heated to sintering temperature of 2800°F. At this temperature, the Calcium Oxide, Silicon Dioxide, Alumina compounds and Iron compounds in the raw materials chemically react to form the calcium silicate and aluminate minerals which are active components of portland cement. The partially fused glassy modules produced in the kiln are called clinkers.

The third subprocess is the cooling. The purpose of this process is to recover the heat while cooling the clinkers fast enough to prevent the degradation of the minerals formed in the kiln. Approximately three pounds of air are used to cool each pound of clinker. About one third of this air goes to the combustion process at a temperature of 1500°F. The remaining air is used to dry raw materials in the raw mill.

The final process in the production is the finish grinding.

In this step, the clinker is reduced in size in two tall mills to 92% minus 45 micron size. Approximately 4% calcium sulfate is added and interground with the clinker to control the salting time of the finished product.

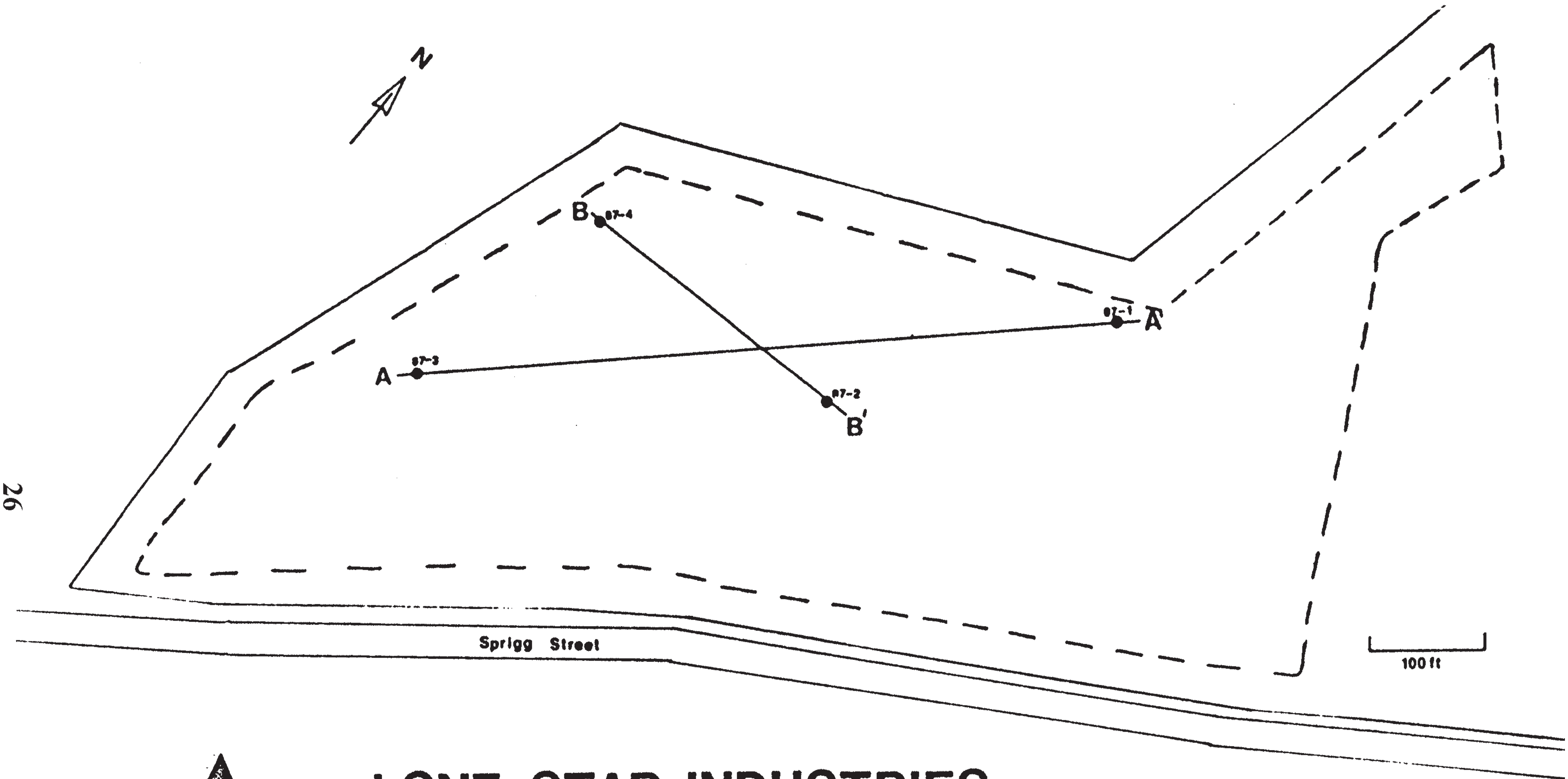
The cement is cooled and tested for uniformity and adherence to government and company standards. The cement is then ready for shipment to either customers or our distribution terminals.

Our distribution occurs mainly on the river with 85% of our production going by barge to terminals in St. Louis, Paducah, Memphis and Nashville.

Future Mining Development

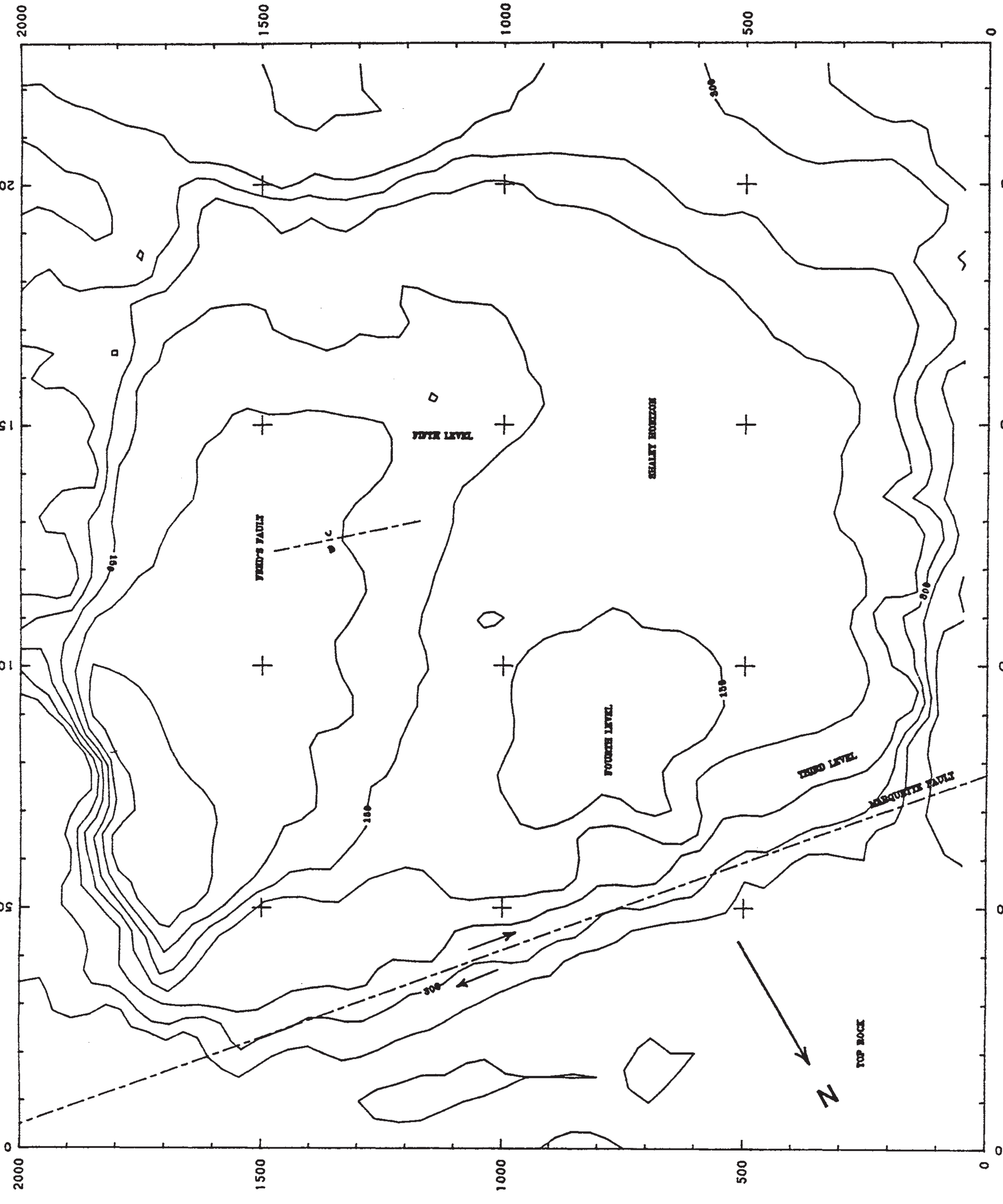
The present pit development has reached the property boundary lines in all directions except to the west. To insure the continued supply of high quality limestone, plans have been developed to open a new mining area by expanding the existing pit in this direction. The new area, which is located behind the Natatorium, has sufficient rock reserves for twenty five years of production at present capacity.

A diamond drill core program was used to test the area's potential, with whole rock analyses performed on site in our quarry control laboratory. Figure 2 shows drill hole and cross section locations for the expansion area. Figures 3 and 4 show the geologic cross sections interpreted from the drilling. Stratigraphy and dip are essentially the same as for the main pit. Figures 5 to 12 show the K_2O and MgO values for production levels down through the 5th level. These values are acceptable for cement production except for the Shaley Horizon which is too high in K_2O and parts of the 5th level which have high MgO levels. However, these rocks will be used by blending with the higher quality top rock to obtain acceptable K_2O and MgO values.



LONE STAR INDUSTRIES
CAPE QUARRY EXPANSION

Figure 2



TOPOGRAPHY OF LONE STAR QUARRY

CAPE GIRARDEAU, MISSOURI

JANUARY 1, 1988

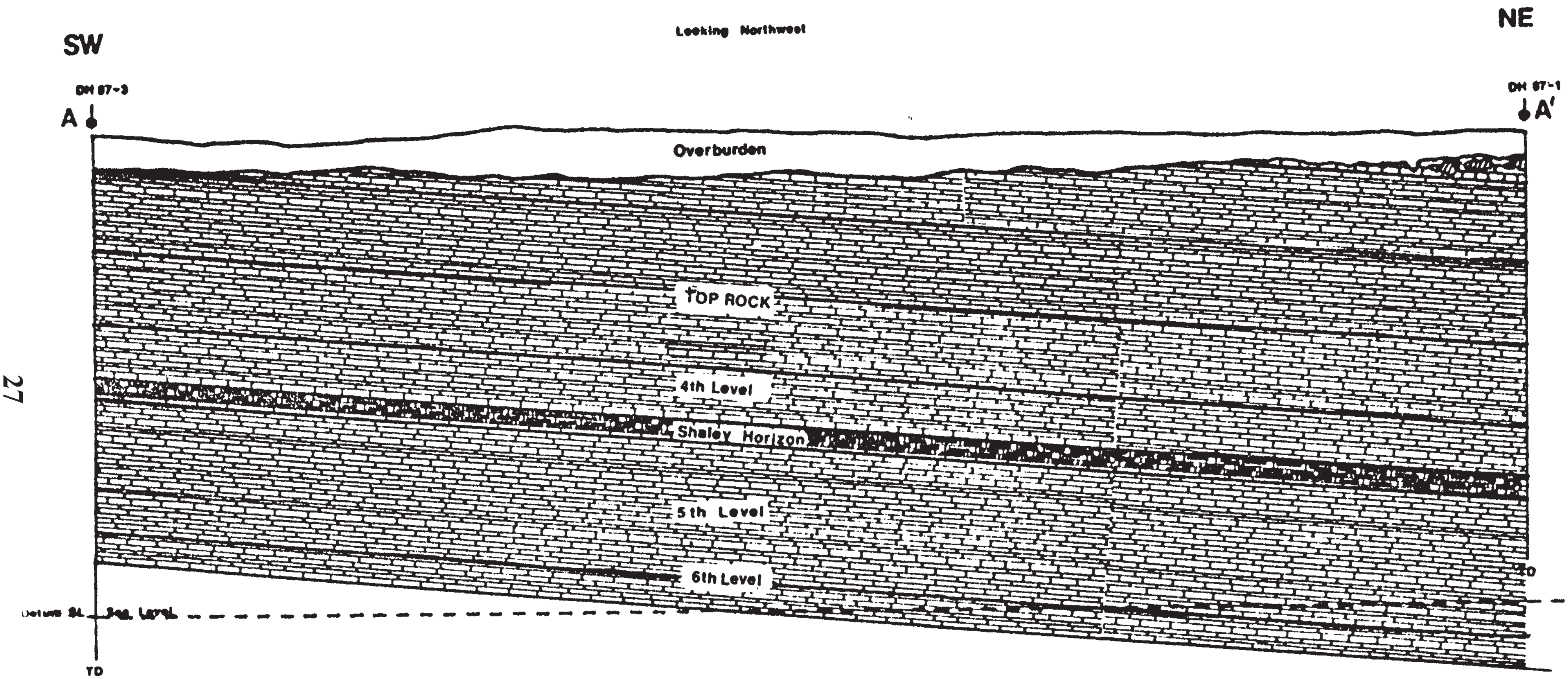


Figure 3. Section AA', Lone Star Expansion

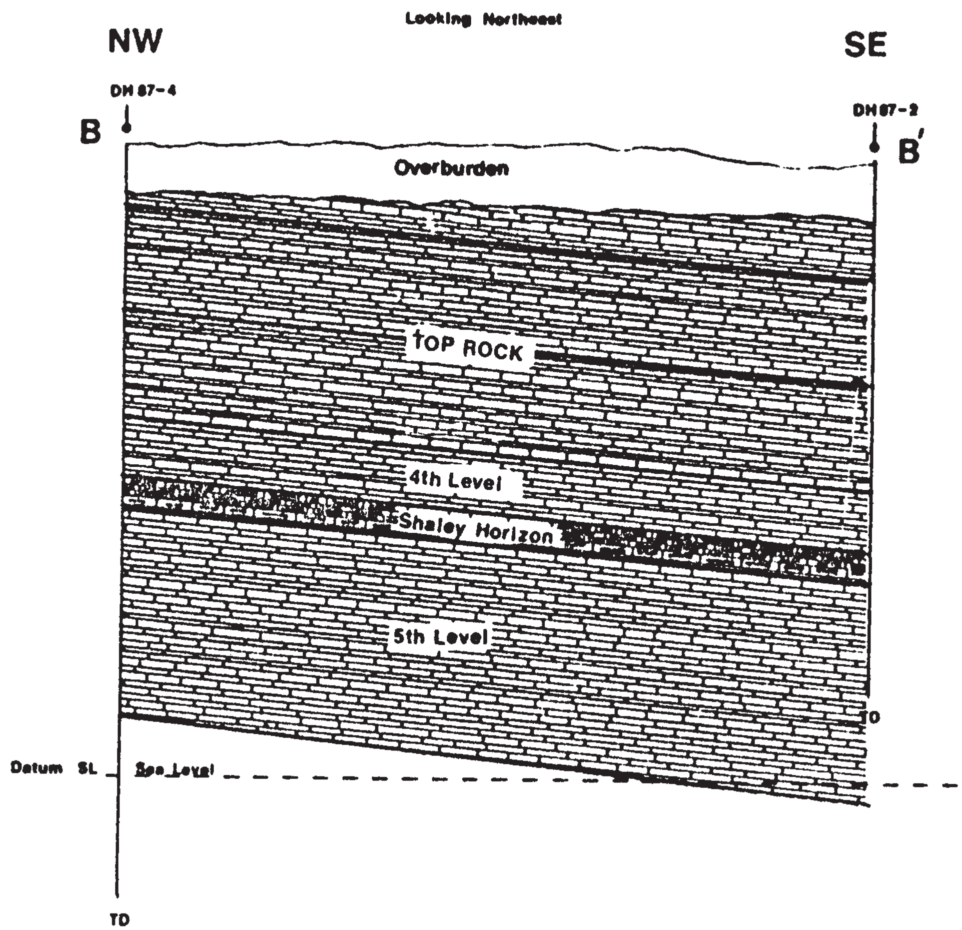


Figure 4. Section BB' Lone Star Expansion

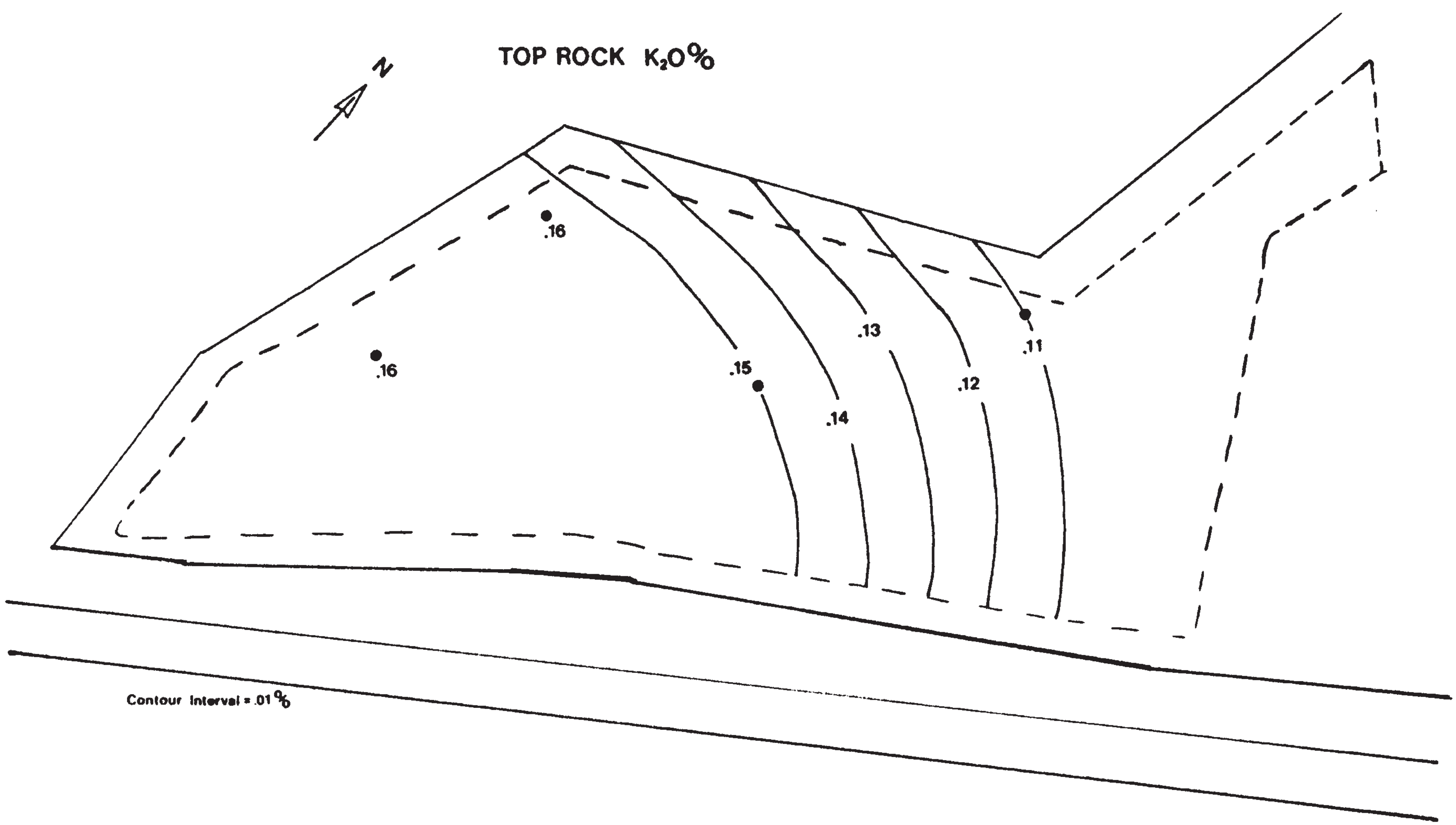


Figure 5

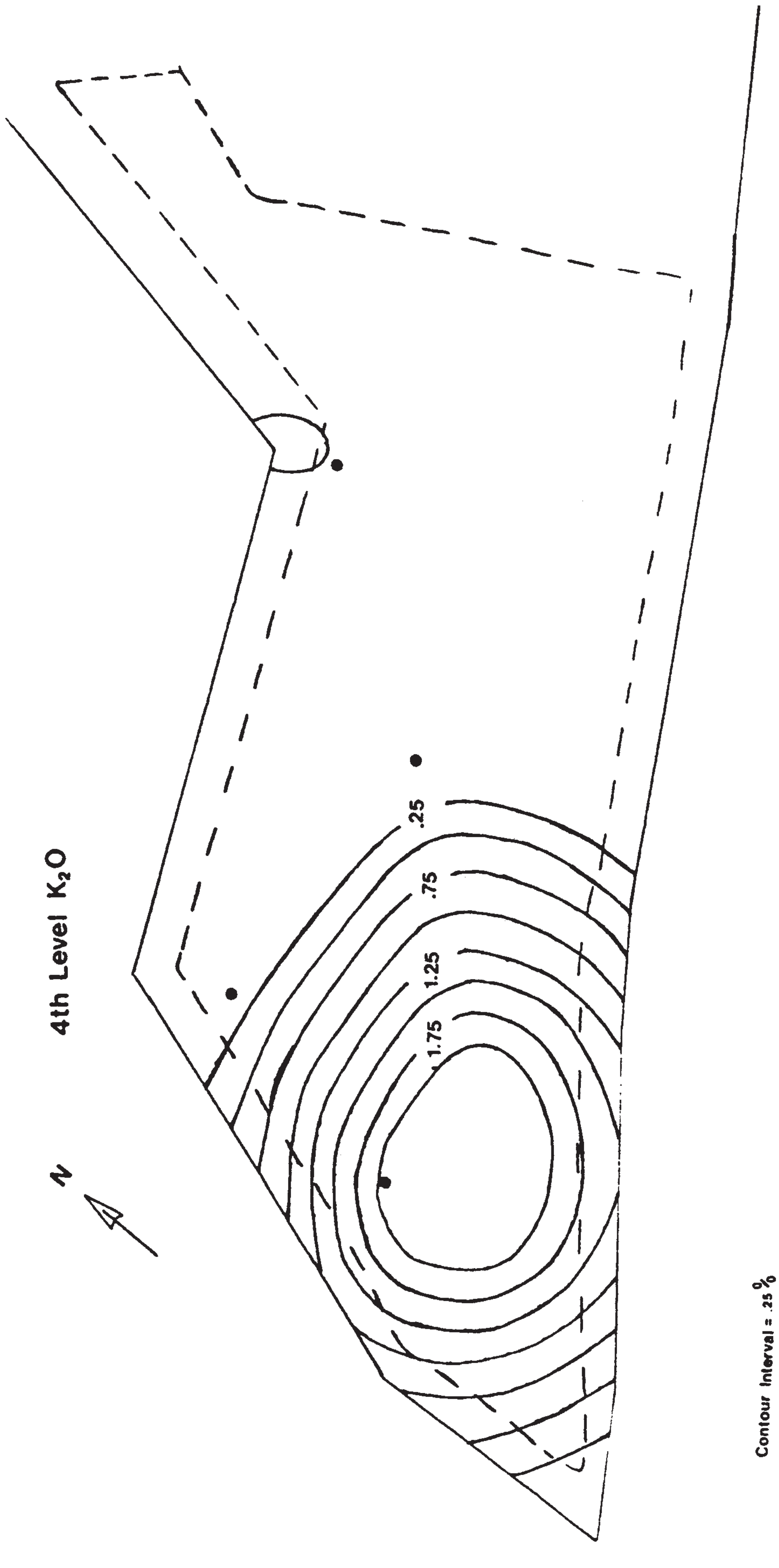
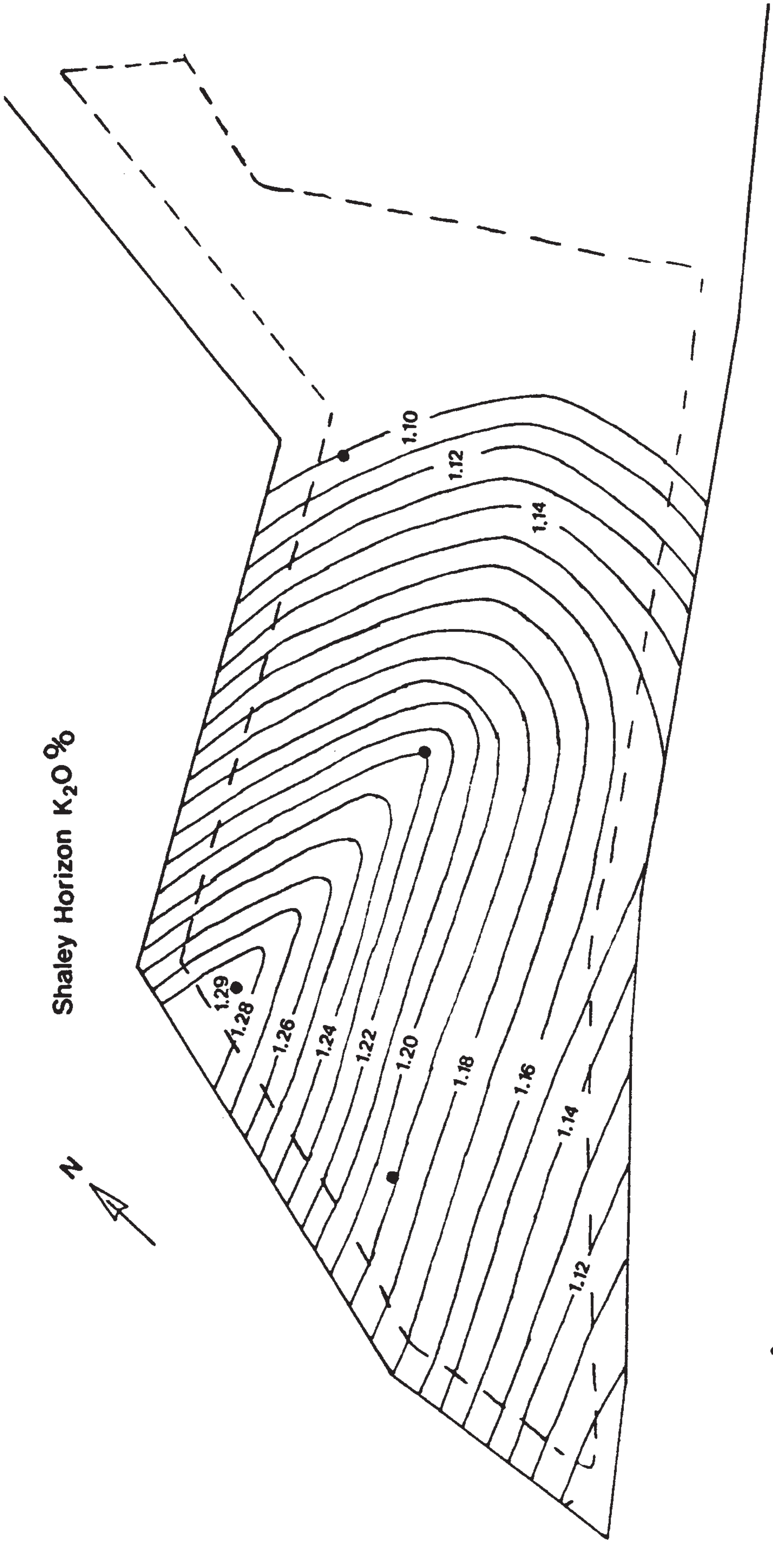


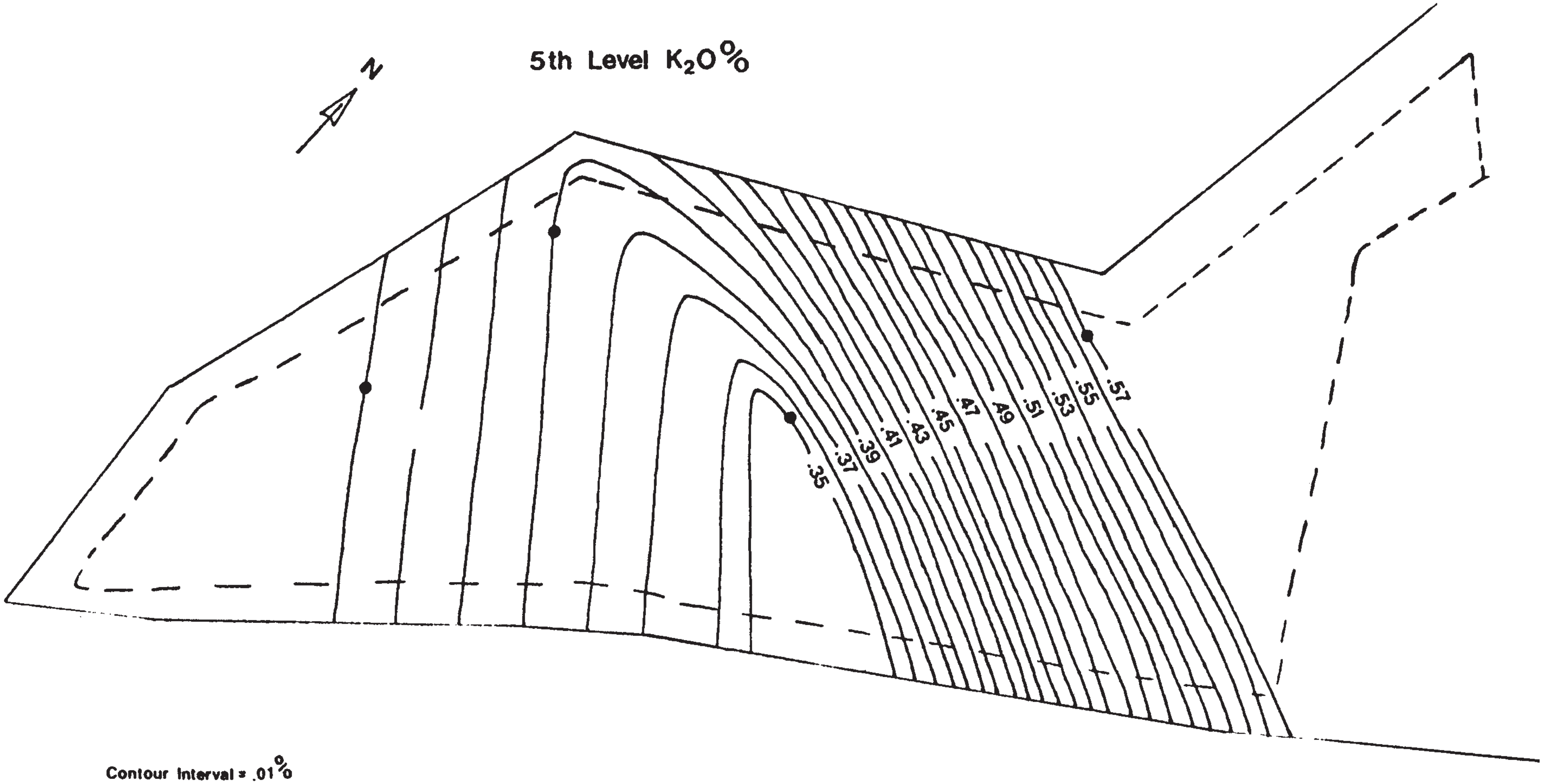
Figure 6

Shaley Horizon K_2O%



Contour Interval = .01%

Figure 7



5th Level K_2O%
N
.35
.37
.39
.41
.43
.45
.47
.49
.51
.53
.55
.57
Contour Interval = .01%

Figure 8

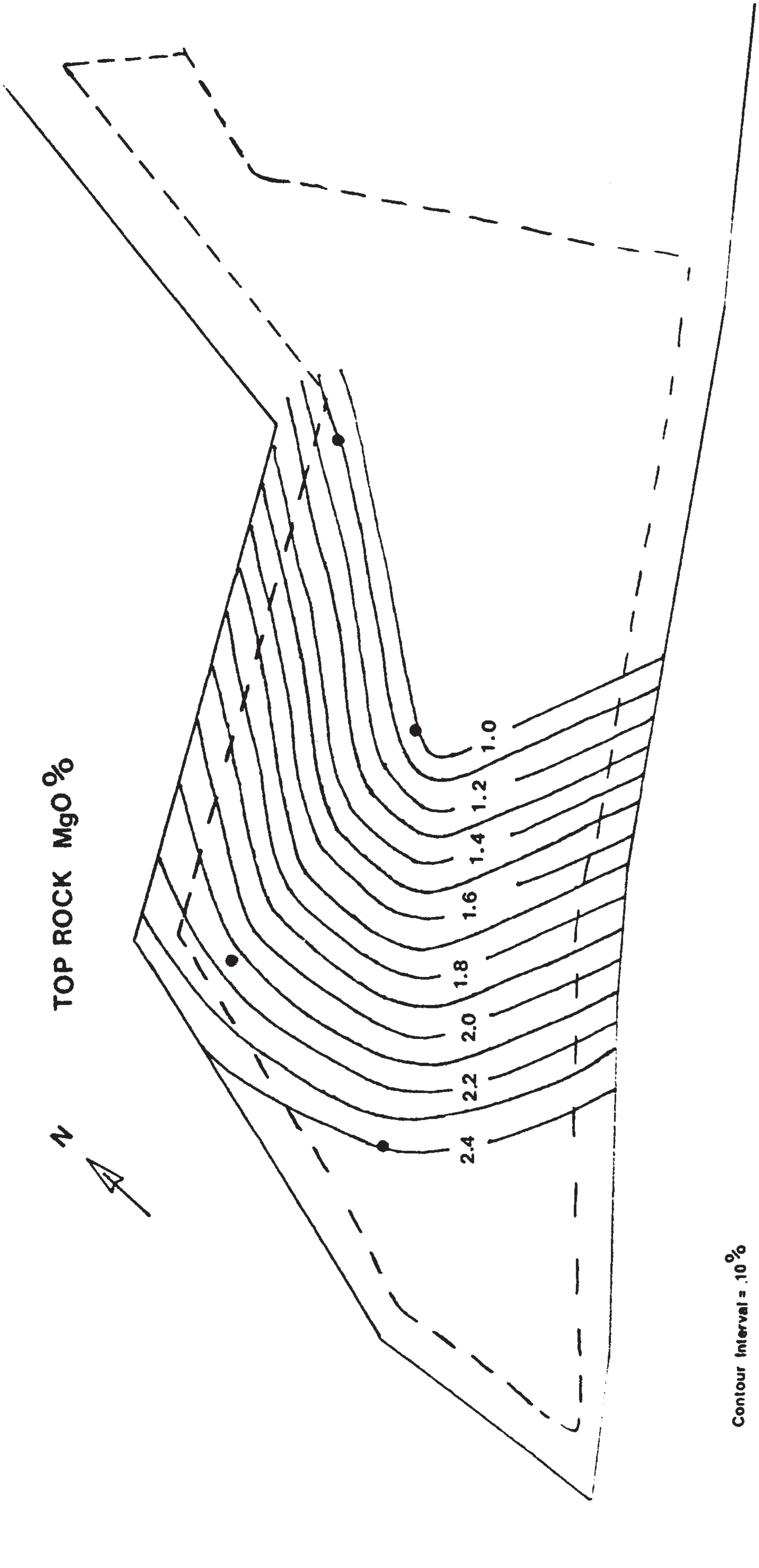


Figure 9

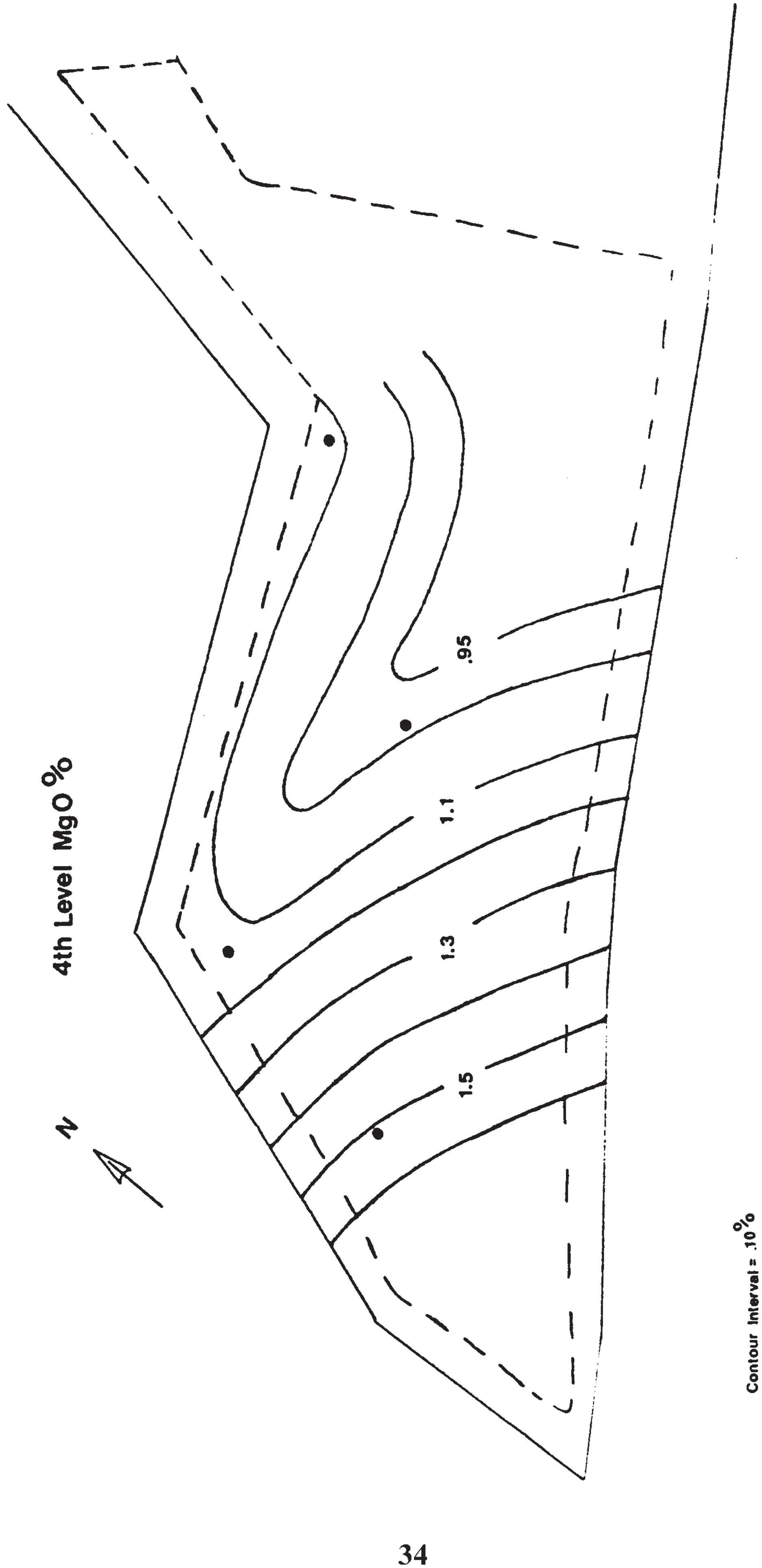


Figure 10

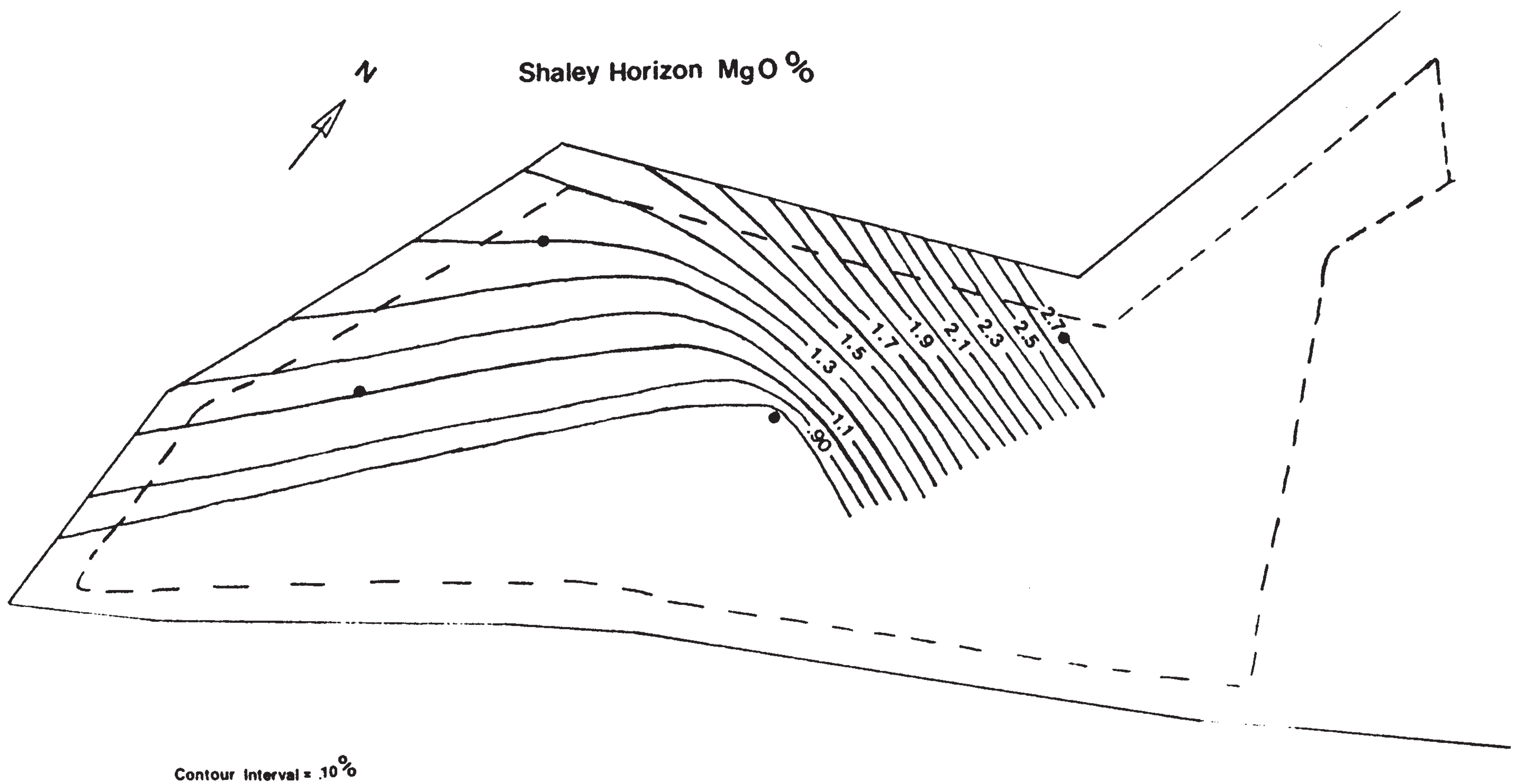

Shaley Horizon MgO %
N
2.7
2.5
2.3
2.1
1.9
1.7
1.5
1.3
1.1
.90
Contour Interval = .10 %

Figure 11

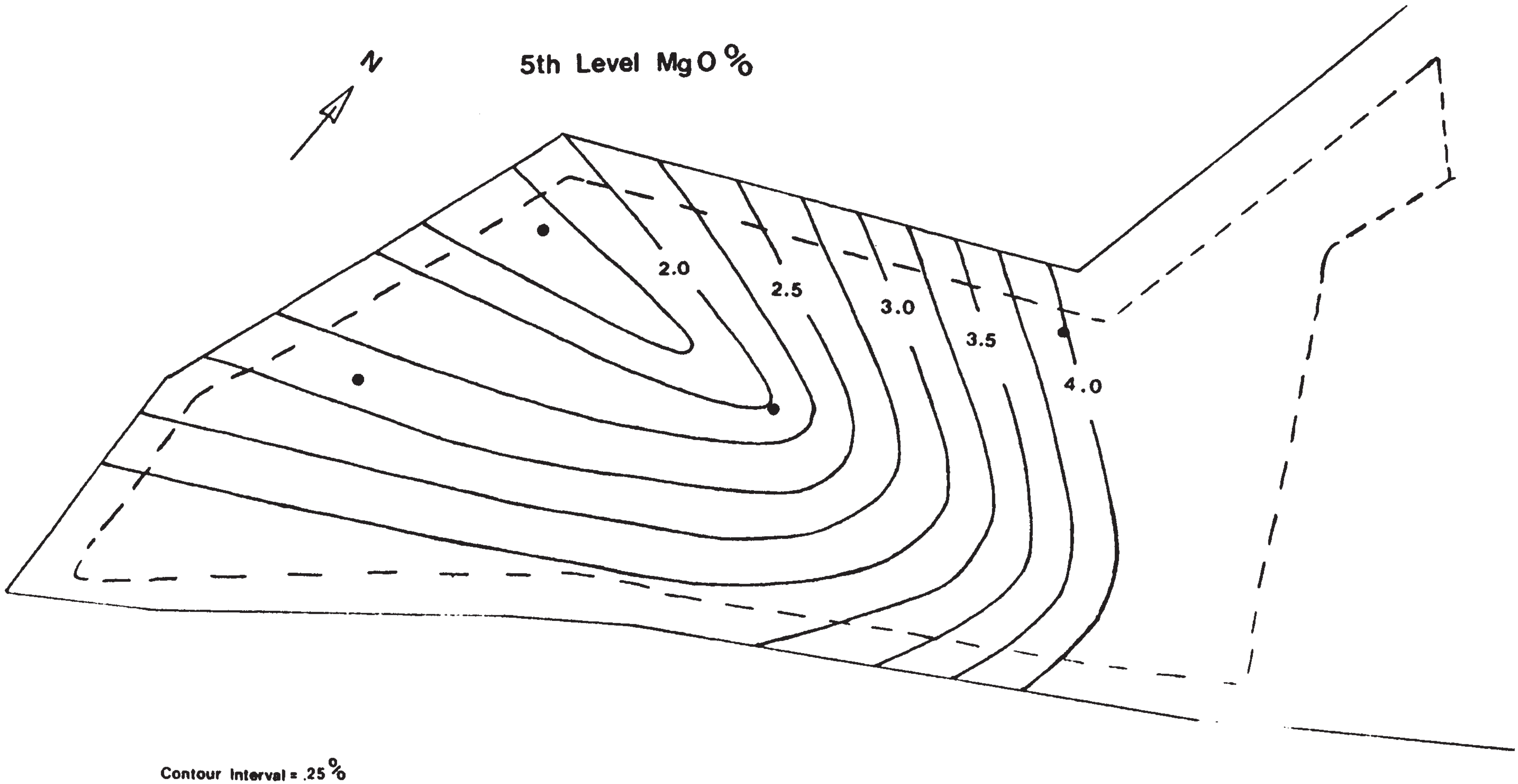


Figure 12

Road Log for Saturday Morning Field Trip

Southeast Missouri Regional Port Authority Facility

	0.0	Leave Holiday Inn. Turn left (west) toward Interstate 55.
0.2	0.2	Turn left (south). Merge onto I-55.
3.1	3.3	I-55 overpasses State 74.
1.0	4.3	Bridge over man-made diversion channel. For the next couple of miles, you may notice Lost Hill to the southwest.

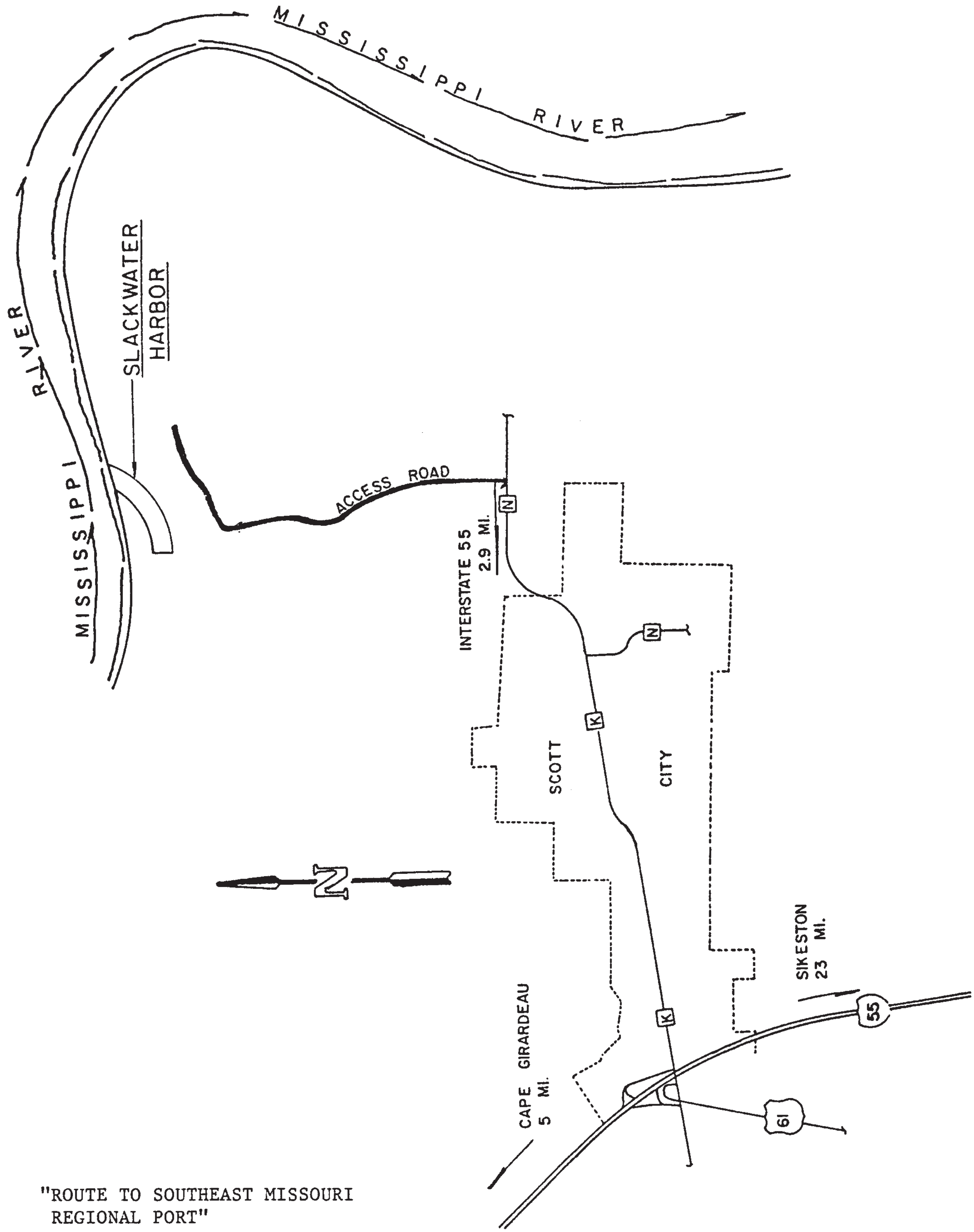
Lost Hill. As we drive southward on I-55 across the Mississippi Diversion Channel, you might notice an island-like hill to the southwest. This is Lost Hill, one of several erosion remnants in the Advance and Morehouse Lowlands. They have resistant Paleozoic cores, but their survival amidst an area of great rivers appears to have been more a matter of luck than resistance.

2.3	6.6	Exit I-55 at Scott City exit.
0.2	6.8	Turn left (east) into Scott City on blacktop K.

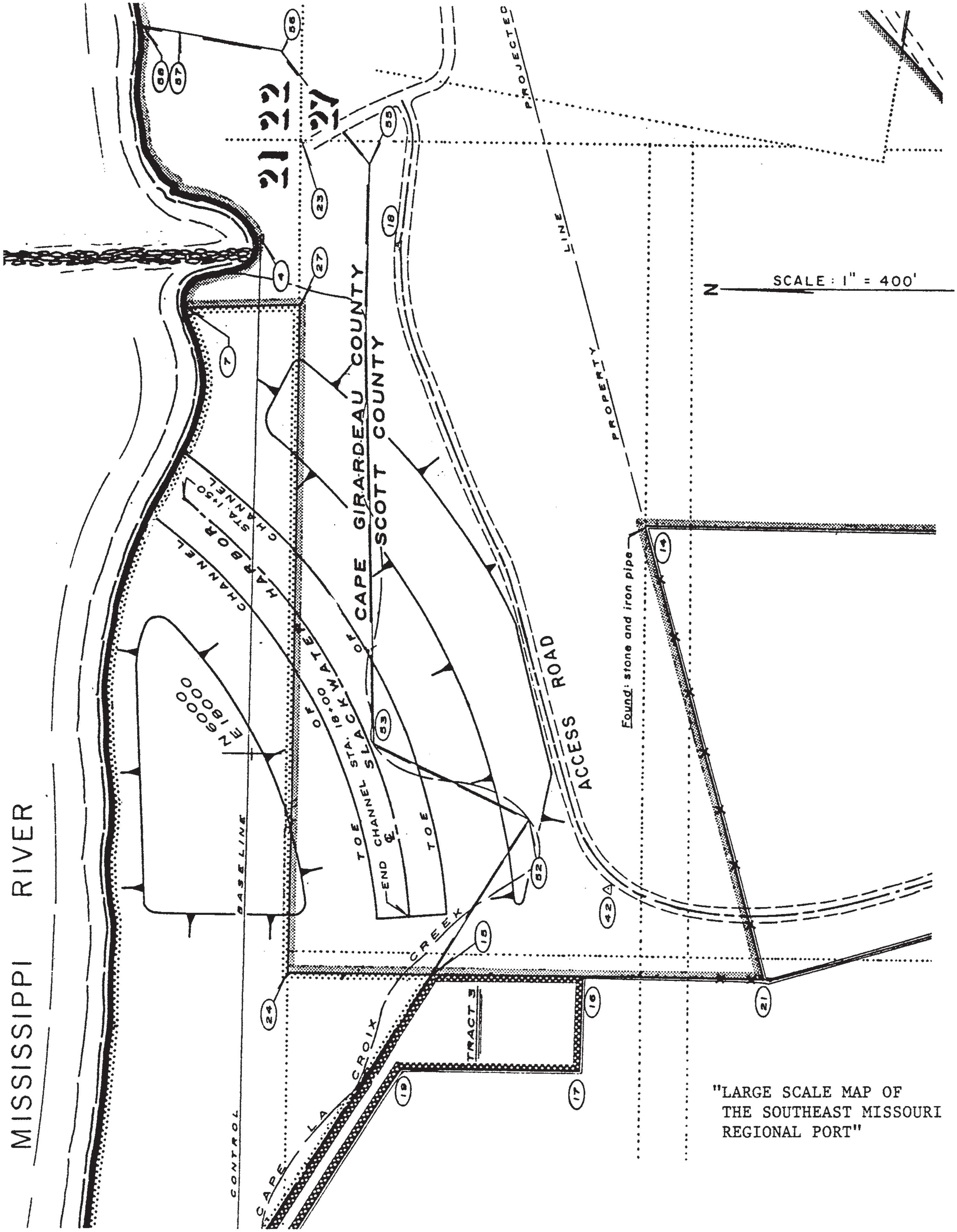
Scott City Channel. Upon exiting I-55 and driving eastward through Scott City, you may notice the long, linear pattern of the city. It is built along a former major drainage that runs east-west, from two miles south of the north end of Thebes Gap to the Mississippi Diversion Channel near Cape airport. This channel contains some 50 feet of alluvium, considerably more than the Mississippi River through Thebes Gap does. This suggests that this channel carried a considerable portion of the flow of the Mississippi for a considerable period of time. It pre-dates Thebes Gap.

2.9	9.7	Turn left (north) onto road with sign proclaiming access to Port. May still be under construction. Drive to Southeast Missouri Regional Port Authority Facilities.

The following map shows the route from I-55 through Scott City to the Port, and following it is a map showing details of the facility site in the vicinity of the slackwater harbor. During the tour Jim Lawson will discuss some of the land survey difficulties encountered in establishing the county line shown on this map.



"ROUTE TO SOUTHEAST MISSOURI
REGIONAL PORT"



"LARGE SCALE MAP OF
THE SOUTHEAST MISSOURI
REGIONAL PORT"

HISTORY OF THE SOUTHEAST MISSOURI REGIONAL PORT

Peter D. Kinder, Port Commissioner
September 1988

The Southeast Missouri Regional Port Authority is a unique entity in state government. It is a creature of statute, specifically a creature of an enabling statute enacted by the Missouri General Assembly in 1974 authorizing the creation of such entities. The SEMO Regional Port Authority was the first to be organized in Missouri under this new legislation, coming into being pursuant to a joint agreement between the County Courts (i.e., administrative bodies) of Cape Girardeau and Scott Counties.

That agreement and the bylaws adopted later called for a nine-member Board of Commissioners to govern the Authority and supervise the design, construction, and operation of a Mississippi River port for the southeast Missouri region. There are four commissioners from each county appointed for four-year terms, and a ninth commissioner is an at-large member selected by the other eight commissioners.

The Board of Commissioners was formed in 1975. That same year Charles Clodfelter, a retired educator, was hired as the first Executive Director by the Board.

Mr. Clodfelter and the commissioners got about the business of trying to develop the port. One of the first decisions made was to locate the port on the Cape Girardeau-Scott County line near Gray's Point east of Scott City, Missouri. 99-year leases were entered into with several landowners for 169 acres of land along the river, while another 108 acres were purchased outright.

Progress on the port was slow at first, owing chiefly to the lack of steady income from any source. The port subsisted off annual appropriations of $10,000 each from Cape and Scott Counties, and from one-time "loans" of $50,000 each from both counties. A small office was opened in Scott City.

In 1984, Mr. Clodfelter resigned his position after nearly nine years of service and the board conducted a broad search for a new Executive Director. After this search, the board hired Tom Cooley, who had been Port Director in Hickman, Kentucky. Cooley assumed this position in June, 1984.

Mr. Cooley worked hard at pursuing a diverse mix of government funding to make the port and its supportive infrastructure a reality.

Approximately $750,000 in state funds from a $600 million state bond issue was committed by the administration of Governor Christopher S. Bond to build a road from Scott City to the port site.

A railroad spur line into the port is being constructed with, among other funding, a $500,000 Community Development Block Grant (CDBG) from the Department of Housing and Urban Development (HUD) and $300,000 from the Federal Railroad Administration.

In late 1984, the board, working in concert with the two County Commissions, decided to place before the voters a tax proposal. A special election was called in Cape and Scott Counties for March, 1985 which sought voter approval for the tax. Voters were asked to approve a ¼-cent sales tax of four-years' duration effective in both counties from January 1, 1986 until December 31, 1989. It was made clear that the tax could not legally be extended without another authorizing vote of the people; that the tax was for four years and four years only. Both counties had to approve the tax by simple majorities or the tax would not have been implemented in either. Approximately $20,000 was raised from business sources and labor unions in both counties to fund the "YES on Proposition Port" effort. There was no active, organized opposition. After a one-week media blitz of television, radio, newspaper, and direct mail appeals, the voters approved the tax proposal by margins of 73 percent in both counties.

Projections which were intentionally drawn up on the conservative side had shown that the tax would produce approximately six million dollars to fund port improvements. Port revenue from this tax has consistently run ahead of these projections, as it is now estimated that the tax revenue will be closer to seven million dollars over the life of the tax.

In early 1986, the Port Authority floated a $4.8 million bond issue against the income stream from this ¼-cent sales tax. These are tax-exempt industrial development bonds similar to the municipal bonds which cities issue. This money went to pay for the Port Authority's share of the dock construction and other infrastructure needs, such as a 10-inch water line and a 250,000-gallon storage tank.

A $1 million grant from the Economic Development Administration (EDA) is also helping fund the dock construction.

In July, 1986, southeast Missouri Congressman Bill Emerson announced to an elated board of commissioners that the Secretary of the Army, who was impressed by the show of local support and commitment demonstrated by the overwhelming approval of the sales tax, had approved $2.3 million for construction of the 1800-foot slack water harbor by the Army Corps of Engineers. This was not all. Not only would the Army Corps of Engineers commit these funds to harbor construction; but the Corps of Engineers committed themselves to a 50-year Operation and Maintenance contract on the harbor, which would include dredging the harbor to permit navigation. This represented an additional commitment by the Corps of $2.5 million over the 50-year life of the maintenance agreement.

In addition, the Port Authority committed $2.1 million in funding to the harbor construction.

It now seemed clear that the long years of work on a regional port for southeast Missouri were coming to fruition.

The Corps of Engineers went to work building the slack water harbor in the summer of 1987 and, aided by excellent construction weather, finished some three months ahead of schedule in March, 1988.

A contract was let for the construction of the dock in May, 1988 with construction set to start in the fall of 1988. Construction of the railroad spur line should follow in 1989, when the completed port facility should be in operation. A targeted marketing effort is under way nationwide to entice industry into the port. Negotiations are currently under way with numerous industries to locate there. These include an ethanol plant, fertilizer and grain companies, and a possible $10 million power transmission line which could bring low-cost, hydroelectric power into the industrial users at the port, as well as a $50 million cogeneration plant which could provide steam to industrial users.

ENGINEERING GEOLOGIC PROBLEMS AND INVESTIGATIONS OF THE SOUTHEAST MISSOURI REGIONAL PORT

Mike Klosterman, Geologist
St. Louis District, Corps of Engineers

Introduction

The proposed Southeast Missouri Port is located in a backwater area of the Mississippi River floodplain on an abandoned channel of Cape la Croix Creek. The total length of the proposed slack water channel is approximately 9500 ft. Planning, design, and construction of the channel is the responsibility of the St. Louis District Army Corps of Engineers. Planning, design and construction of docks, warehouses, and other shore facilities is the responsibility of the Southeast Missouri Regional Port Authority. An initial 1800 ft. channel excavation has been completed to elevation 296 ft. NGVD, approximately 40 feet below the natural ground surface (Figure 1).

Site Description

A typical soil profile at the site would consist of thick deposits of Mississippi backwater clays underlain by alluvial sand which continues to bedrock. The clay is gray to dark brown, mixed with gray to brown silt and some fine, silty sand. The underlying sand is gray, fine to coarse grained with traces of gravel throughout. The old abandoned channel of Cape la Croix Creek meanders across the floodplain at the site and crosses the proposed channel excavation at several sites. The channel fill material consists of typical stream deposits of alternating thin to medium lenses of clay and silt with occasional thin lenses of fine sand.

Bedrock beneath the site is a massive, dark gray, finely crystalline limestone of the Plattin Formation. In the adjacent bluffs, the formation has weathered to a grayish-white and contains small caves and large, open joints. Nearby, Westlake quarry extracts the Plattin. A 3-5 ft. displacement purportedly occurred during the 1811-12 New Madrid earthquake in the limestones of the Plattin and overlying Kimmswick Formations in a small quarry reportedly located just south of the project area. However, this site has now been covered by quarry debris and can no longer be seen.

Subsurface Investigation

Between 1980 and 1982 eight borings and a seismic refraction survey were done at the proposed harbor site to determine site suitability. A four-inch bucket-type auger and a 1 3/8-inch ID splitspoon were used to obtain soil samples. Soils consisted of a brown sandy to silty clay of medium plasticity (CL) mixed with a dark gray inorganic clay of high plasticity (CH). The total thickness of the clay was 20 to 30 feet. Beneath the clay was from 50 to 130 feet of fine to coarse-grained, poorly graded, alluvial sand with traces of gravel.

Rock core was obtained with a PQ-sized (4 1/16-inch ID) wire line, double barrel sampler. Boring 1C encountered rock at elevation 267 MSL and 25 ft. of core was obtained. This core was gray to dark gray, hard, dense, shaley limestone, fine to coarsely crystalline with numerous small, open, subhorizontal fractures and many calcareous shale partings. The rock core was identified as the Plattin Formation. Laboratory testing of soil samples consisted of sieve analyses, natural moisture contents, and Atterberg Limits.

A seismic refraction survey was also performed to determine the depth to bedrock along the centerline of the proposed 9500 ft. harbor excavation. A Geometrics ES 1210 refraction seismograph using twelve geophone channels was used. Kinestik, a two component explosive detonated with a blasting cap, was used as the energy source. Thirty 400 ft. seismic lines were run, most parallel, but some transverse, to the channel centerline. Depth to bedrock solutions were plotted and are shown in Figure 2.

In 1986 a second phase of subsurface exploration was performed to develop design parameters for the soil excavation, channel slope stability, and fill placement. Nineteen borings were taken in the area of the 1800 ft. channel excavation and fill area (see Figure 3). Depth of borings ranged from 35 to 90 feet. No bedrock was encountered. All borings were sampled at 5-foot intervals. General samples were obtained using a 1 3/8-inch diameter drive tube sampler. Undisturbed samples were taken of the clay strata in five of the borings using a 5-inch diameter, thin wall, fixed piston sampler. Soil consisted of 30 to 40 feet of firm, moist, mottled gray clay of medium to high plasticity. The clay contained traces of sand, iron oxides, and organic material. The underlying sand, which ranged up to 50 feet in thickness, was gray, fine to coarse grained with traces of gravel, and poorly graded. The clay-sand contact occurred between elevation 301 and 289 ft. NGVD. Laboratory testing of the soil consisted of water content determination, grain size analyses, Atterburg limits, triaxial compression test (Q-test), direct shear tests, and unconfined compression tests.

Available test data indicates that the foundation clays have Liquid Limit values between 50 to 105 and Plastic Index values between 27 to 76. The majority of natural moisture content values range between 30% to 50%. Free groundwater was encountered in the borings at approximately elevation 310 feet, but rose to an elevation of approximately 330 feet after completion of the hole indicating a hydrostatic head of 20 feet. When a boring completely penetrated the impervious upper strata and extended into the pervious sub-strata, groundwater elevations were found to reflect the Mississippi River stage. However, when a boring was stopped short of the previous sub-strata and allowed to stand open for 24 hours, groundwater levels were found to be approximately 20 ft. lower.

Stability Analysis

Prior to channel excavation, long term stability analyses were run for a typical channel section consisting of 1V on 3H side slopes with 100 ft. of foreshore from the top of the channel cut. The dry and wet fill areas and the retention dike surrounding the disposal area were also checked and analyzed for sliding stability. The long term stability analyses were based to shear strengths with an internal angle of friction (phi) of 18 to 20 degrees and cohesion (c) of 0 psf. These analyses indicated a marginal factor of safety of 1.01 to 1.10. The channel side slopes being predominantly a CH type clay soil, exhibit a large shrink swell potential, especially along the upper portion of the slope. This contributes significantly to the development of surface tension cracks during periods of hot dry weather. These cracks not only reduce the overall safety of the slopes through a reduction in shear strength, but could also fill up with water, causing additional stress to the slope as well as decreasing the strength of the soil by saturation and weathering. This potential for damage will increase with cycles of cracking and swelling. Therefore, while the overall slope design is acceptable with respect to deep full section slide development, the channel slopes have the potential for the development of shallow slides of limited vertical and horizontal extent. The existence of weaker horizontal soil layers or silt/sand layers would increase that potential. Flattening of the slopes will reduce this potential for development of shallow slides to occur but there is no way to completely eliminate them. The establishment of a good grass cover plus an active riprap maintenance program will provide the best means of controlling the long term stability problems.

Construction

The area was cleared of vegetation and construction begun in the summer of 1987. Excavation of the initial 1800 foot channel was completed in January, 1988. The initial channel excavation of 1800 ft. was accomplished to elevation 296 ft. NGVD, approximately 40 feet below the natural ground surface. The channel slope was laid back to 1V on 3H and protected with 18-in. graded stone to an elevation of 320 feet except in the area where piles were to be driven for the docking and warehouse facilities. The material was excavated from the channel using landbased equipment and was deposited as compacted fill on the natural ground surface a minimum of 100 ft back from the highbank of the channel. The material dredged from the channel was deposited in a retention area surrounded with retaining dikes (see Figure 4).

Landslides

In the late fall and early winter of 1987, earthslides developed in two separate areas on the landward side of the excavated channel (see Figure 5). Subsequent field and subsurface investigations indicated that the slide was confined to the area where the old Cape la Croix channel transected the excavation for the port channel and was probably triggered by the removal of lateral support when the channel for the port was excavated. The soil appears to be sliding into the excavation on the thinly bedded, weak silts of the old stream channel deposits. These stream channel deposits were initially thought to extend to elevation 330 ft., or about 10 ft. deep. Subsequent investigations, however, showed them to extend to a depth below the bottom of the channel excavated for the port or to about elevation 290 ft. The absence of rip rap slope support in this area and the presence of water in the thin sand lenses of the stream channel deposits contributes significantly to the problem. Possible remedial measures for eliminating the slide include construction of a groundwater cutoff across the old channel upstream of the slide, installing drains, flattening the slope, adding rip rap to the slope, removing some or all of the material, and loading the toe of the slide. No decision had been made at the time, of this writing regarding what remedial measures will be employed.

FIGURE 1

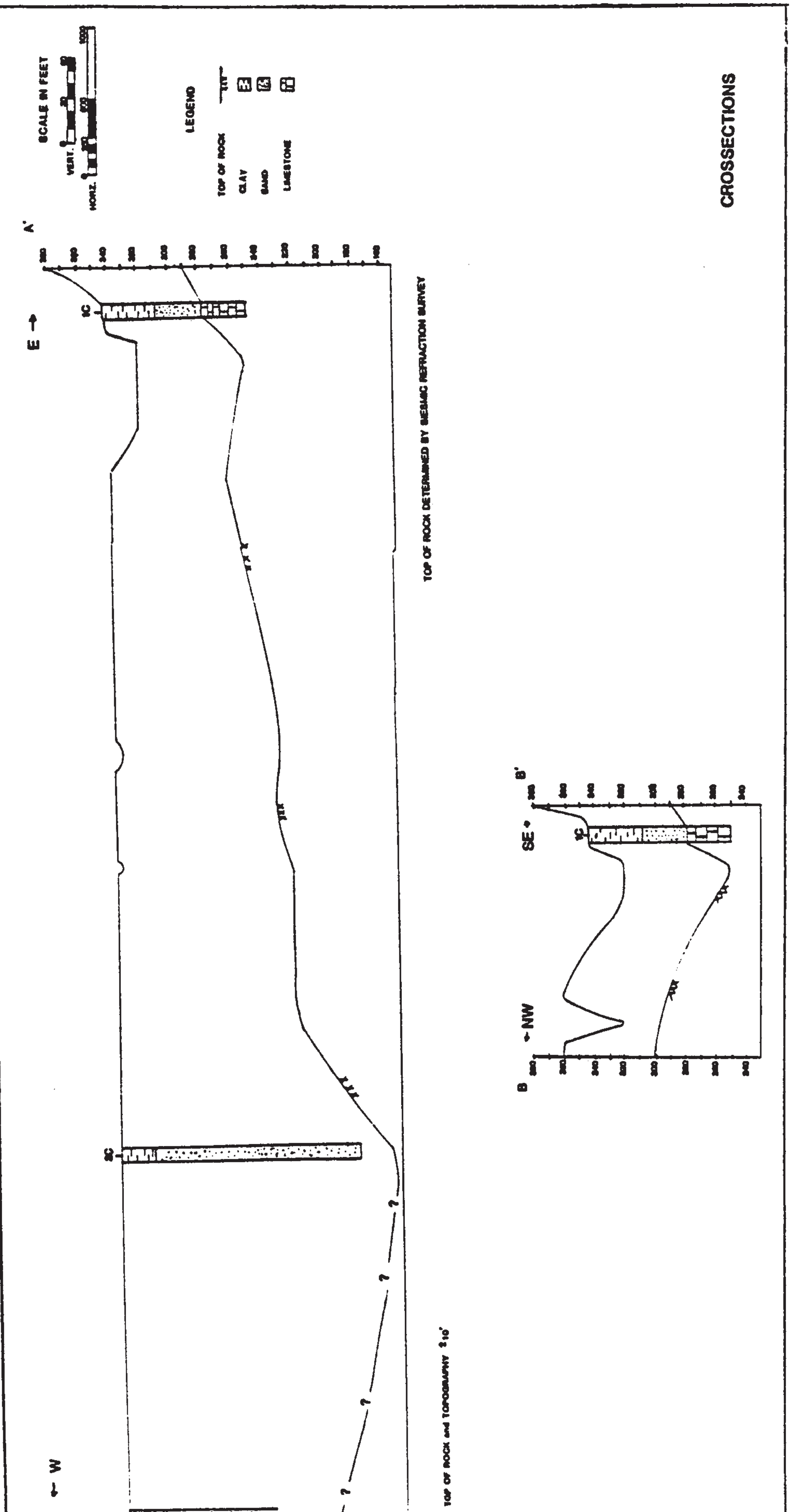

SCALE IN FEET
LEGEND
TOP OF ROCK
CLAY
SAND
LIMESTONE
CROSSECTIONS
TOP OF ROCK DETERMINED BY SEISMIC REFRACTION SURVEY
A
A'
B
B'
E →
← W
SE →
← NW

FIGURE 2

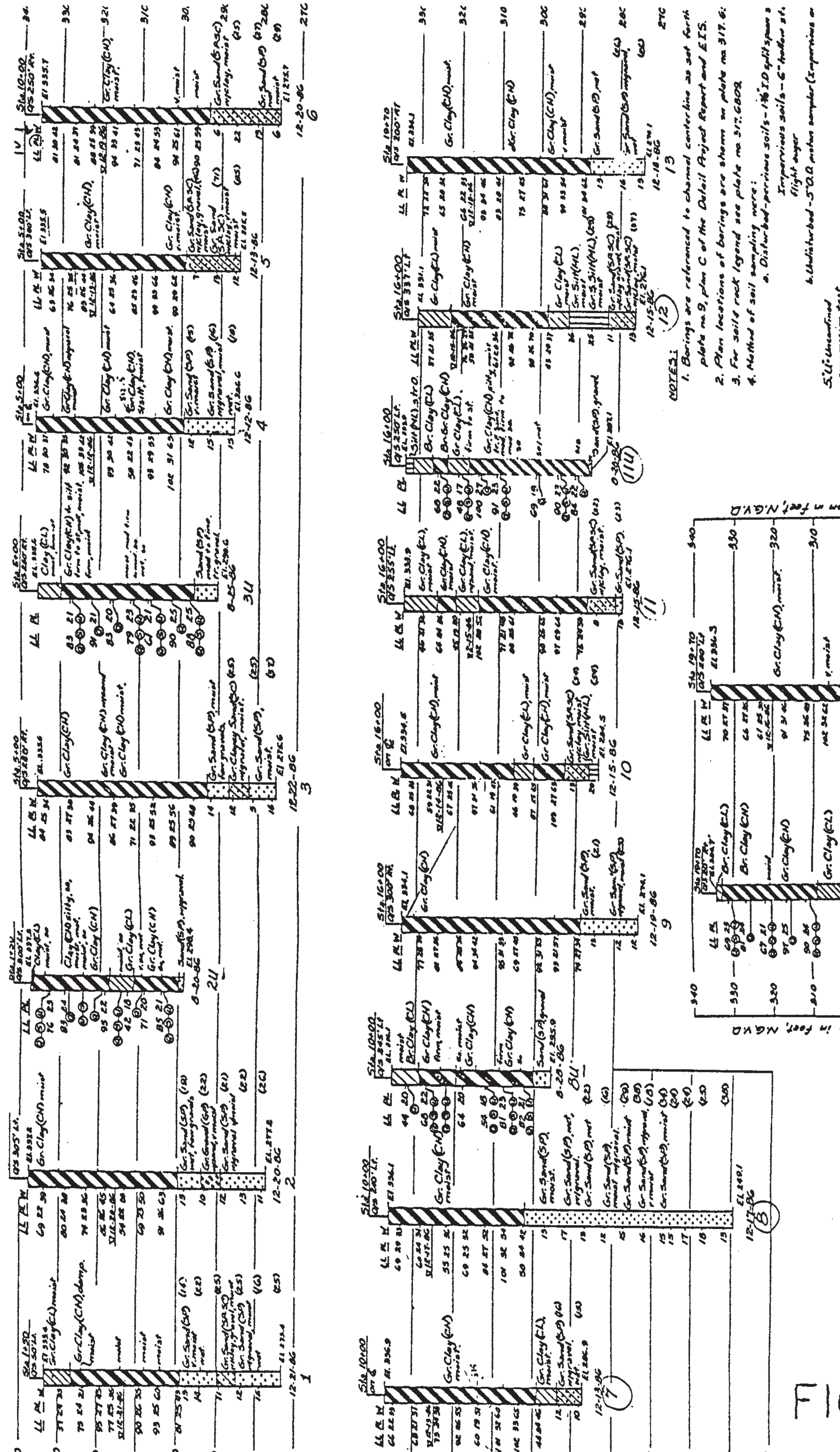
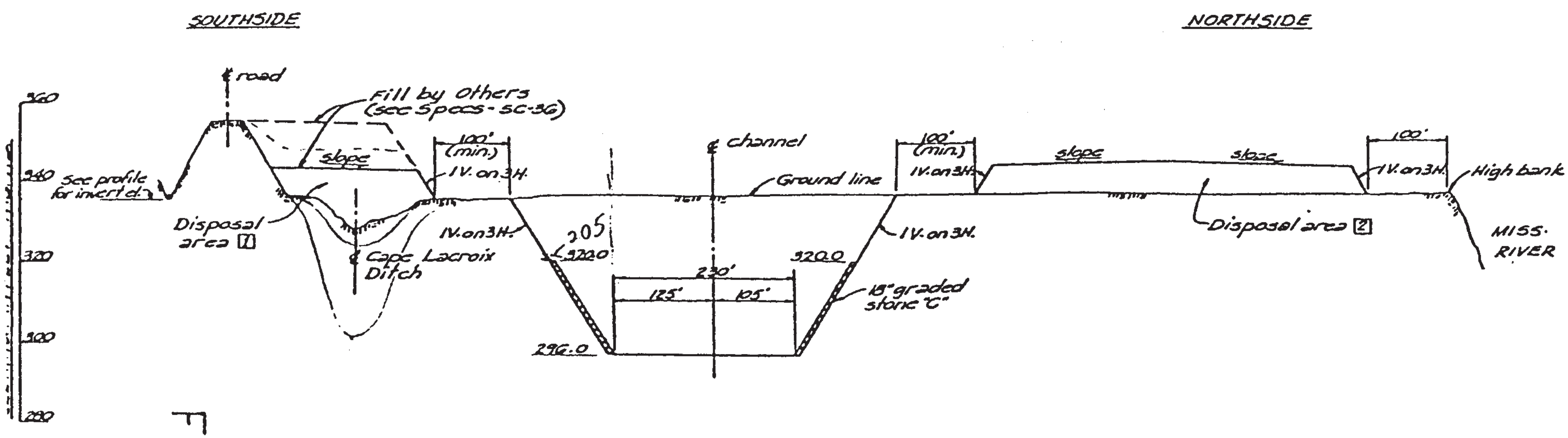

NOTES:
1. Borings are referenced to channel centerline as set forth plate no. 9, plan C of the Detail Project Report and EIS.
2. Plan locations of borings are shown on plate no. 317.6:
3. For soil & rock legend see plate no. 317.6809.
4. Method of soil sampling were:
a. Disturbed-pervious soils-1⅜" I.D split spoon s
Impervious soils-6" hollow st. flight auger
b. Undisturbed-5" O.D piston sampler (Impervious so
5. "U"= Unconfined compression test.
Elevation in feet, N.G.V.D.

FIGURE 3



SECTION A-A

SCALE: 100' 0 100'

FIGURE 4

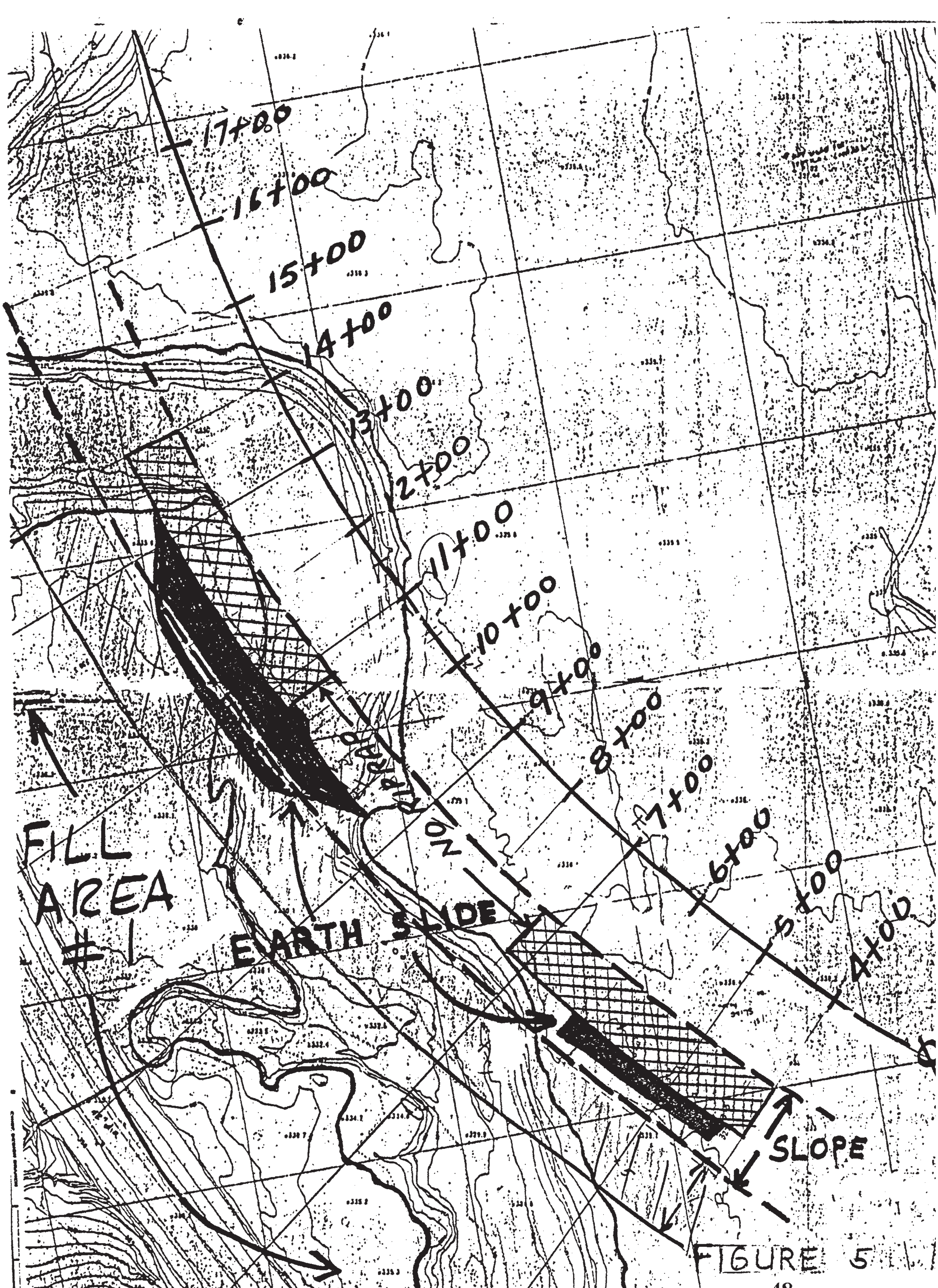

17+00
16+00
15+00
14+00
13+00
12+00
11+00
10+00
9+00
8+00
7+00
6+00
5+00
4+00
FILL AREA #1
EARTH SLIDE
SLOPE

FIGURE 5

On the Origin of Thebes Gap

B. Ray Knox
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Editor's note: This paper was first presented in the 1981 AMG guidebook. It is reprinted here because Thebes Gap lies just south of the Southeast Missouri Port. During our Saturday morning field trip Ray Knox will expound on the geologic history of the Gap and Mike Klosterman will discuss the Corps of Engineers work on improving the navigation channel in the Gap where much of the Mississippi River bed is bedrock.

To obtain a broader background for and understanding of the Thebes Gap area, consult the report by Ray Knox on the Upper Mississippi Embayment which follows this report.

ABSTRACT

Thebes Gap, located five miles south of Cape Girardeau, Missouri, is a segment of the Mississippi River valley which has no floodplain. The courses of the Mississippi River, the Ohio River, and north flowing stream which once existed at the present site of Thebes Gap have all experienced drastic changes in the recent geologic past. A recent major change involving all three streams was the diversion of flow of the Mississippi River across a seven mile segment of the Benton Hills. It is hypothesized that a combination of drainage basin piracy and climatically controlled river alluviation led to the creation of Thebes Gap.

INTRODUCTION

Thebes Gap is the term applied to that segment of the Mississippi River between Gale, Illinois and Commerce, Missouri. In this 6.7 mile segment, the river has no floodplain and essentially flows over bedrock. These factors, along with the increased gradient, the rapids, and the intense mass wasting of the valley walls, testify to the extreme geologic youth of this feature.

PREVIOUS INVESTIGATIONS

C. F. Marbut, in 1902, described the evolution of the northern part of the southeast Missouri lowlands. He attributed the drainage changes to stream piracy guided by differences in erosion resistance between the Mississippi north of the Benton Hills and the Ohio, which flows on less resistant strata.

D. R. Stewart (1942) did a great deal of general field work in an area which included the Benton Hills. He did some detailed work in the immediate vicinity of Commerce, including a large number of shallow cores. This work includes evidence for relatively recent deformation in the Commerce area, the Benton Hills, and the Bloomfield Hills.

N. H. Fisk, in 1944, published his monumental, classic work on the alluvial valley of the lower Mississippi River. He included a hypothesized chronology for the drainage evolution of the study region, relating the most dominate changes to glacioeustatic control of base level.

P. E. Potter, in 1955 in a pair of papers discussed the origins of the Lafayette gravels. He interpreted these high, enigmatic deposits as locally derived, preglacial alluvial fan deposits, spread by high velocity streams.

Geologists and geophysicists of the United States Geological Survey, the Missouri Geological Survey, and the Illinois Geological Survey, and other agencies, have conducted recent investigations which include the study area. None of these deal directly with the origin of Thebes Gap, and these research efforts only indirectly involve Thebes Gap. Most of the reports of these activities can be found through a relatively complete bibliography at the end of this report.

GEOMORPHIC FACTORS A VALID HYPOTHESIS MUST ADDRESS

A hypothesis, to be valid, must take into consideration several regional and local geomorphic phenomena which are almost certain to be closely related to the evolution of Thebes Gap. Some of these follow:

1. Evidence suggests the former existence of a north flowing stream system whose main channel occupied the position of the present Thebes Gap. Fisk (1944) pointed out that tributary streams flowing into the Mississippi River within Thebes Gap join the Mississippi with acute angles pointing northward, suggesting a drainage reversal has taken place in times too recent for the tributaries to have made adjustments. The projected elevations of the former junctions decrease northward, as would be expected if the trunk stream then flowed northward.

2. Evidence suggests that the former drainage basin of the ancestral north flowing stream system extended considerably further south of the present southern margin of the Benton Hills. Fisk (1944) attributed this to basin piracy of the ancestral Ohio River. The present drainage divide lies very close to the south edge of the Benton Hills.

3. Evidence suggests the existence of a former east-west trending channel which flowed through the present location of the Scott City railroad yard and the main street of Scott City. The geomorphic history of this feature awaits further research.

4. The drainage evolution of the Thebes Gap cannot be isolated from the evolution of the other Mississippi River former drainage courses. The evolution of changes involving the Ohio and Tennessee Rivers should also be taken into account.

GEOMORPHIC HISTORY OF THEBES GAP - A WORKING HYPOTHESIS

At the present state of research, the following generalized sequence of events is suggested:

Phase One. Pre-diversion. Possible late Wisconsin.

During latest Wisconsin-earliest Holocene time stream discharges were high due to glacial meltwater. The gradients of the major rivers were steep, due to low sea level. Major rivers were cutting deeply into their former deposits, and into bedrock, eroding deep valleys.

1. The Mississippi River was flowing west-southwest through the present site of the Cape Girardeau municipal airport through the Drum Lowland.

2. The Ohio River was flowing west-southwest through the Cache Valley, eroding away the southern portion of the Benton Hills, including the headwaters of the north flowing stream which occupied the present site of the Thebes Gap.

3. An ancient stream was flowing southwest through that part of the present Ohio River valley from near Metropolis past Cairo, then southward.

4. The Tennessee River was flowing northeast and then north past Paducah, where it joined the Ohio River near Golconda at the east end of Cache Valley.

Phase Two. Beginnings of Diversion. Early to Mid Holocene.

The climatic changes which controlled the glacial-interglacial stages were swinging once again toward increasing aridity. As meltwater discharges decreased, valley cutting decreased, gradients became less steep as sea level rose, and valley alluviation began, largely from fans built outward from tributary streams. Sediment availability became increasingly controlled by the decreasing vegetation cover, and less so by reworking glacial deposits.

1. Mississippi River drainage was increasingly diverted through the Bell City-Oran Gap.

2. The Ohio Rover was diverted south of Cache Valley into its present course past Paducah and Cairo.

3. High Water overflow began through the beheaded basin at the south end of the present Thebes Gap. This backwater overflow gradually increased with succeeding floods.

4. An east-west channel formed, flowing past Illmo and Scott City. This channel could have evolved from an original tributary of the north flowing Thebes Creek. The direction of this flow appears to have been mostly toward the east-northeast, but could have been partially west-southwest in the western half.

Phase Three. Full Diversion. Late Holocene.

Glacial meltwater was no longer a factor in discharge. Sea level continued to rise. Gradients of major streams continued to decrease. Sediment availability was largely controlled by harsh mechanical weathering allowed by the more sparse vegetative cover. This sediment was introduced into the Mississippi intrenched valley largely as alluvial fan deposits. The river reworked and spread this material, building itself higher and higher, until backwater from floods began to overflow the beheaded divide of the ancestral south-flowing Thebes Creek basin.

1. The Mississippi River was diverted through Thebes Gap by overflowing the lowered divide during flood times. As this flow increased, the flow through the Bell City-Oran Gap decreased.

2. The Mississippi-Ohio junction changed from far south of Cairo to near Cairo.

3. Only relatively minor drainage changes have occurred since the Thebes Gap diversion.

OTHER FACTORS WHICH MAY HAVE CONTRIBUTED

Factors other than those described above may have contributed to the evolution of Thebes Gap. Some of these follow:

1. Rising sea level during late Wisconsin-early Holocene time as a result of glacial meltwater pouring into the world ocean. Fisk (1944) believed this to be the primary control of deposition as far upstream as the middle Mississippi Valley. Other workers feel this factor has influenced deposition only within a short distance of the coastline.

2. Regional epeirogenic uplift since Tertiary time. Several investigators, including Potter (1955), believe this to be the major control of stream regimens in the upper Mississippi-Ohio alluvial valley.

3. Regional and/or local deformation by folding and faulting. Several field studies have strongly suggested geologically recent folding and faulting in the area. Stewart (1942) and some more recent investigators have suggested the possibility of post-Lafayette or even post-loess faulting.

4. Varying efficiency of weathering processes due to climate oscillations. Total availability of sediment may be greater as a result of alternating Holocene arid-humid cycles than by more static arid or humid climates.

FURTHER RESEARCH

Many of the hypotheses outlined above need to be thoroughly tested by detailed field investigations. The origin of Thebes Gap is but one event in the larger, overall evolution of the geomorphology of this part of the world. Much work remains.

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The Geomorphic Evolution of the Upper Mississippi Embayment

Ray Knox

Editor's note: This paper was first presented in Probauger, newsletter of the Missouri Association of Professional Soil Scientists, volume 28, 1986.

The Upper Mississippi Embayment constitutes that portion of the Gulf Coastal Plain that swoops northward into a big inverted "V" up the Mississippi Valley with Cairo, Illinois, setting about at the point of the "V". This great alluvial valley is largely a product of the Mississippi River and its tributaries. The Mississippi River system has reacted through geologic time to changing conditions, largely controlled by changing climates.

Before the Pleistocene Ice Age, the ancestral Mississippi River system drained a much smaller area than it now does (Figure 1). Much of the northern part of the present drainage basin flowed to the north and northeast, and much of the present-day eastern part then flowed to the east. The Ohio River was a relatively small tributary at that time. The major tributary entering the Mississippi River from the east was the Teays River, which drained much of the area now assumed by the present Ohio River. The Teays River valley is now entirely buried under glacial till.

The drainage patterns of the upper and middle Mississippi Valley were permanently changed by the advancing Ice Age glaciers. Actually, there were four ice advances (glacials) that were most prominent, separated by time of retreat (interglacials). The present-day course of the Missouri River was pretty much established by the second (Kansan) glacial advance. The Missouri River was then an ice marginal stream, and its course marks the southernmost ice advance of the western part of the Mississippi Valley. In a similar way, the present course of the Ohio River pretty well marks the southernmost ice advance of the eastern half of the Mississippi drainage basin. The third (Illinoian) glaciation made it farthest south in that area. The combined effect of these events was to suddenly (geologically speaking) double the area drained into the Mississippi River. All of this added runoff with all of the sediment carried by these tributaries was funnelled into the lower Mississippi Valley. The "neck" of the funnel was the Upper Mississippi Embayment.

During the Ice Age (1.6 MYBP - 11,000 YBP) the big rivers reacted to the numerous ice advances-retreats by alternately cutting and filling the lower Mississippi Valley. If we could see through these river deposits, we would see that they have buried two great canyons or trenches (Figure 2). These trenches were cut during an early Ice Age downcutting episode.

During each of the four glacial episodes, precipitation was relatively high, the glaciers grew and advanced southward, stream discharges were high, the vegetative cover was thick, sediment supply was controlled, sea level was low, stream gradients were high, and the rivers tended to downcut. During each interglacial, precipitation was relatively low, the glaciers retreated, stream discharges were high with meltwater at first -- then greatly reduced, sediment supply was high at first due to glacial outwash -- then later due more to reduced vegetative cover, sea level was high, stream gradients were low, and rivers tended to fill their valleys with their deposits.

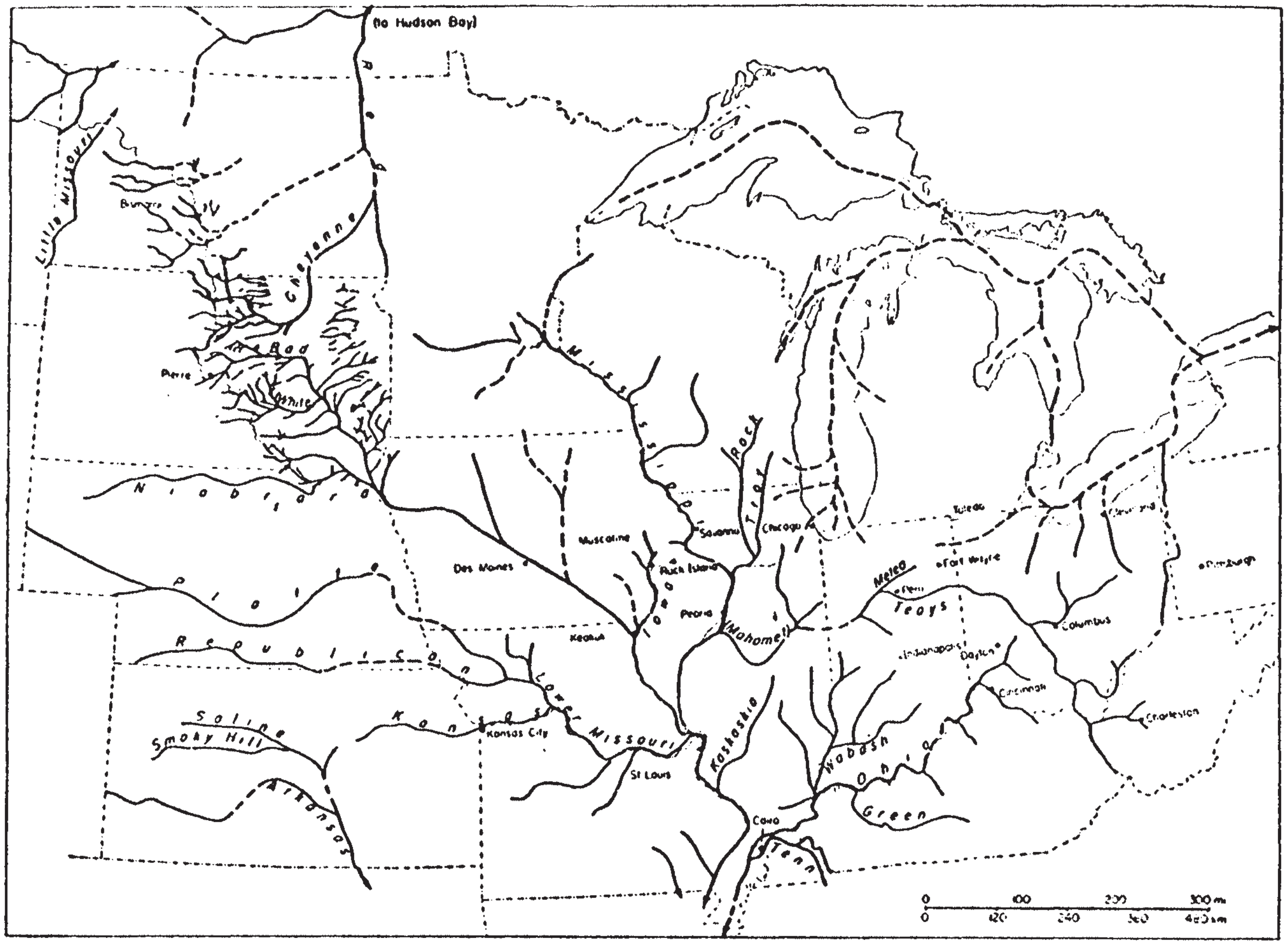

Figure 1. Ancestral Mississippi River System (after Flint, R. F., 1957, Glacial and Pleistocene Geology, Wiley, p. 170)

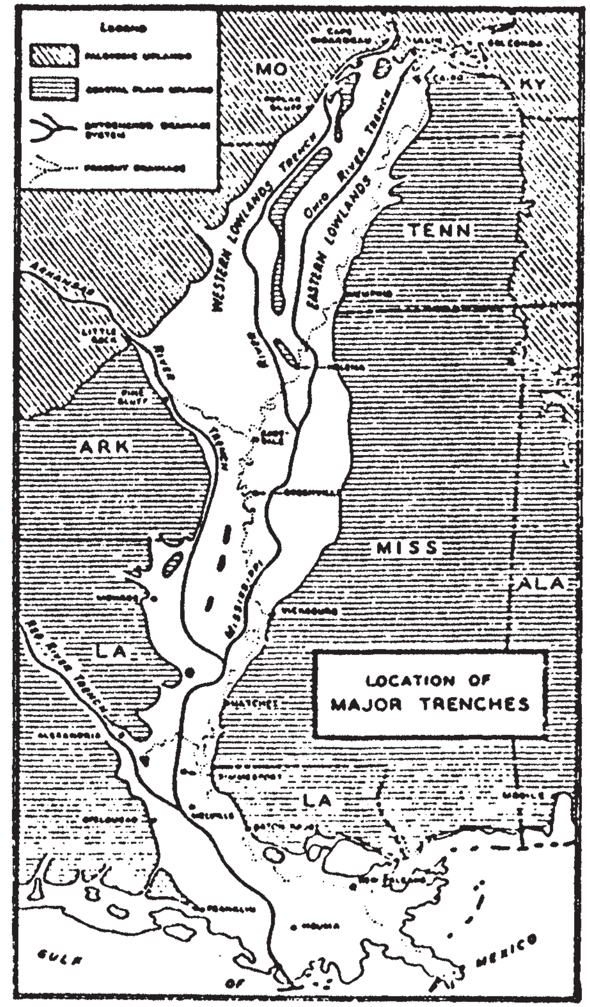

Figure 2 (after Fisk, 1944)

The alternating cut-fill episodes resulted in multiple paired terraces in the lower alluvial valley. Fisk's terraces (Figure 3) are probably overly idealistic, but they are helpful in understanding the major concept.

The last major ice advance, the Wisconsinan, contained a relatively arid interlude within it. This time of relatively low precipitation, around 20,000 YBP, was a time when wind erosion is thought to have manifested itself in two ways in the Upper Mississippi Valley. (Saucier, 1978). Fine grained material (primarily silt) was relatively unprotected by the sparse vegetative cover and by the wide, braided streams. Wind picked much of this up and redeposited it as a loess "blanket". The intermediate sized material (primarily sand) was moved closer to the ground, being redeposited as sand dunes.

As the last ice advance melted away, the great trenches were filled for the last time. At first, graveliferous glacial outwash filled in the lower parts. Then, increasingly, sediment derived from nonglacial sources added to it. As the valleys became more and more filled, diversions of the courses of the major rivers began to occur. The Ohio River diverted from the Western Lowlands past Poplar Bluff to the Morehouse Lowland, between Bell City and Oran. This course change left the combined flows of the Whitewater, Castor, St. Francis, Black, and Current rivers in the Western Lowland. These course changes are dated as early as 17,000 YBP by Saucier (1974) or as late as 6000 YBP by Fisk (1944).

The period around 7500-4500 YBP was another relatively arid episode. Trees and shrubs declined, allowing herbs to increase. This "Altithermal" interval allowed wind to once again become a relatively more effective erosion agent. Sand dunes became reactivated because of the thinning vegetative cover, and mounds of loess were resettled, probably in the patchy clumps of grassy vegetation which produced wind shadows for the dust to settle in (Quinn 1958). This process probably produced the "prairie mounds" that exist by the hundreds of thousands, not only in the alluvial valley, but in several states.

A final major river diversion, involving the Mississippi River, is thought to have occurred about 6000 YBP (Saucier 1974) or as recently as 2000 YBP (Fisk 1944). This was the abandonment of the Morehouse Lowland in favor of the new course through Thebes Gap (Knox 1980).

Another process that appears to have had an effect on the evolution of landscapes of the Upper Mississippi Alluvial Valley is liquefaction resulting from earthquakes. Evidence is mounting that precursors to the notorious 1811-1812 earthquakes have occurred at least several times before that event. Sand blows, lateral spreading, and associated slope failures around escarpments have all been attributed to earthquakes by recent researchers.

		GLACIATED AREA		LOWER MISSISSIPPI VALLEY
		GLACIAL STAGES	INTERGLACIAL STAGES	INTERGLACIAL TERRACE DEPOSITS
		Each glacial stage characterized by accumulation of ice upon continents and lowering of sea-level with resultant entrenchment of streams and valley cutting.	Each interglacial stage characterized by retreat of ice sheets from continents and rise of sea-level with alluviation of valleys cut during previous glacial stage.	Each terrace deposit is of interglacial age, fills valleys cut during preceeding glacial stage, and constitutes a geologic formation. Continued uplift during Quaternary Period has raised terrace deposits above level of present floodplain.
QUATERNARY PERIOD	RECENT EPOCH			RECENT ALLUVIUM (RA)
	PLEISTOCENE OR GLACIAL EPOCH	Late Wisconsin (youngest)		Valley cutting VC-5
			Peorian	PRAIRIE FORMATION (PF)
		Early Wisconsin		Valley cutting VC-4
			Sangamon	MONTGOMERY FORMATION (MF)
		Illinoian		Valley cutting VC-3
			Yarmouth	BENTLEY FORMATION (BF)
		Kansan		Valley cutting VC-2
			Aftonian	WILLIANA FORMATION (WF)
		Nebraskan (oldest)		Valley cutting VC-1

IDEALIZED RELATIONSHIP OF TERRACES

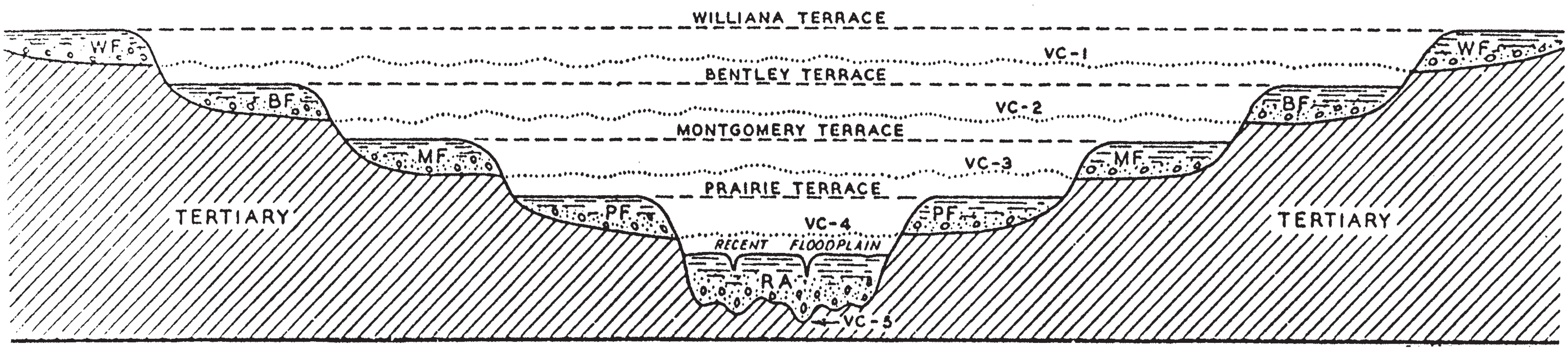

Figure 3. Pleistocene History of the Central Gulf Coastal Plain (after Fisk, 1944)

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Cape Girardeau Area: Historical and Cultural Setting

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Editor's Note: This short article and the following area map are provided for those of you planning to explore some of the local history and culture of the Cape Girardeau Area. I highly reocmmend Bollinger Mill State Park for both its scenic and historic significance. I also like Altenburg, and the restaurant there is reported by reliable sources to be excellent. The antique railroad operating out of Jackson may also be of interest. One of their runs includes dinner. Trail of Tears State Park has a new visitor's center and some great views of the Mississippi River.

Enjoy your visit to the Cape Girardeau Area!

Cape Girardeau began as a French trading post in the mid-1700's, but few French families ever settled in the area. The primary group of pioneers who settled the county were Anglo-Americans from Virginia, Kentucky, Tennessee, and, most significantly, North Carolina. They came in the 1790's and first decade of the 1800's while the west side of the Mississippi River was Spanish territory. So the land survey system in Cape Girardeau county derives from the Spanish land grant system, typically squares without north-south orientations.

These first Anglo-Americans were part of the regional culture called the Upper or Upland South. This regional culture developed in the Shenandoah valley of Virginia and the piedmont of North Carolina. It was formed from two colonial seaboard culture areas -- southeastern Pennsylvania and the Tidewater Chesapeake Bay of Virginia and Maryland. The Pennsylvanians moved southwest down the Great Valley of the Ridge and Valley system in the 1720's where they intermingled with Southerners moving west from the coastal plain and piedmont in the 1760's. The fusion of these two peoples with contrasting value systems and attitudes formed the Upper South culture. This culture is quite distinct from the Deep or Lower South plantation culture based on cotton that formed in the South Carolina and Georgia piedmonts in the early 1800's and spread west through the Gulf states.

The Upper Southern culture had a series of distinct ethnic groups from its two origin areas. The Pennsylvanians had three groups, the English Quakers, Germans (so-called Pennsylvanian Dutch) and the Scotch-Irish or Ulstermen. The Southerners had two ethnic groups: the English and African. As these groups moved west different combinations emerged forming a series of complex cultural patterns in the trans-Appalachian areas of Kentucky, Tennessee, and Missouri.

Here in Cape Girardeau County the Scotch-Irish and Germans of Pennsylvanian origin and the English Southerners of Tidewater Chesapeake Bay origin became the 'first effective settlement society'. This term used in cultural geography refers to the group that settles an area in sufficient numbers to create a society and culture which later immigrants acculturate to.

These later immigrants were Germans who mainly came from Hannover and Brunswick in the 1830's and 1840's. By 1860 German immigrants accounted for almost half of the population of the county.

In northern Cape Girardeau county Germans originally from Saxony settled in Old Appleton and Pocahontas. The Saxon German core was in southern Perry county in Wittenburg, Frohna, and Altenburg where they had founded the mother church of the Missouri synod Lutherans. These Germans developed the typical settlement patterns of the Strassendorf (street village). They also speak German in the highest proportions in the whole state, about a quarter of Perry county's population.

Cultural sites to visit in the area include the following from north to south:

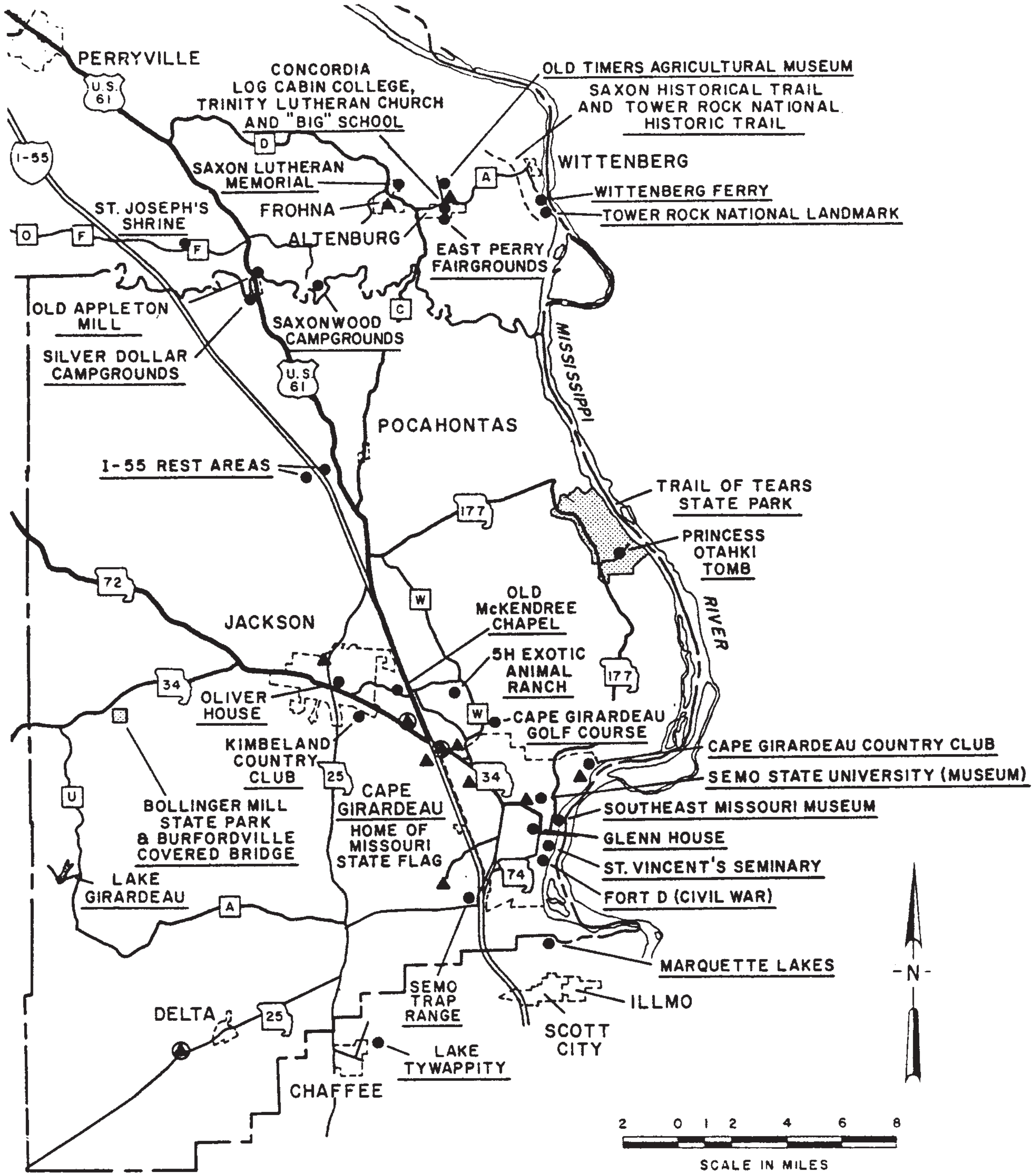
(1) Altenburg - Saxon German strassendorf village. Note the immaculate hedgerows and the growth of clover in the surrounding farms. A few of the houses have the fachwerk, (half-timbering) construction. The mother church of the Missouri synod Lutherans is worth seeing.

(2) Jackson - Several homes remain from the early period -- the Oliver house being an example which can be toured. The courthouse square plan is unusual, having north-south streets approaching the middle of the block.

(3) Burfordsville - Bollinger's mill and covered bridge is one of two sites in the country where a historic mill and covered bridge are adjacent. Burfordsville originates from Pennsylvanian Dutch who came from North Carolina.

(4) Cape Girardeau - Several sites are worth seeing. The downtown area along the river preserves several historic structures. The most famous building is U. S. Grant's headquarters during the Civil War, presently occupied by the restaurant, Port Cape Girardeau. The Glen House is an excellent example of Victorian architecture. St. Vincent's cathedral and nearby former college are in the river area as well.

(5) Kelso and New Hamburg. These two German villages south of Cape Girardeau derive from German Catholics who settled in the area in the mid-1800's.



POINTS OF GENERAL INTEREST IN THE CAPE GIRARDEAU AREA

PRIMARY TOUR ROUTE

SECONDARY TOUR ROUTE

TOUR SIDE TRIPS

▲ LOCAL PARK

ROADSIDE PARK